Postrelease Performance of Natural and Hatchery Subyearling Fall Chinook Salmon in the Snake and Clearwater Rivers

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2008 IMPLEMENTATION SUMMARY

In 2008, we continued a multi-year study to compare smolt-to-adult return rate (SAR) ratios between two groups of Snake River Basin PIT-tagged fall Chinook salmon *Oncorhynchus tshawytscha* that reached the sea through a combination of either (1) transportation and inriver migration or (2) bypass and inriver migration. We captured natural subyearlings rearing along the Snake and Clearwater rivers and implanted them with passive integrated transponder (PIT) tags, but knew in advance that sample sizes of natural fish would not be large enough for precise comparisons of SAR ratios. To conduct the study, we captured natural subyearlings rearing along the Snake and Clearwater rivers and implanted them with PIT tags. Because we could not collect sufficient numbers of natural fish to conduct a study that would provide precise comparisons of SAR ratios, we supplemented the treatment groups with PIT-tagged Lyons Ferry Hatchery subyearlings raised under a surrogate rearing strategy and released them into the Snake and Clearwater rivers. The surrogate rearing strategy involved slowing growth at Dworshak National Fish Hatchery to match natural subyearlings in size at release as closely as possible, while insuring that all of the surrogate subyearlings were large enough for tagging (i.e., 60-mm fork length). Surrogate subyearlings were released from late May to early July 2008 to coincide with the historical period of peak beach seine catch of natural parr in the Snake and Clearwater rivers. We also PIT tagged a large representative sample of hatchery subyearlings reared under a production rearing strategy and released them into the Snake and Clearwater rivers in 2008 as part of new research on dam passage experiences (i.e., transported from a dam, dam passage via bypass, dam passage via turbine intakes or spillways). Culturing production subyearlings is a higher priority than culturing surrogate subyearlings. It involves accelerating growth at Lyons Ferry, Nez Perce Tribal, Umatilla, and Oxbow hatcheries, sometimes followed by a few weeks of acclimation at sites along the Snake and Clearwater rivers before release from May to June. In this report, we construct passage indices at Lower Granite Dam for the Snake River basin populations of natural and production subyearlings. At the simplest level, this objective illustrates the difference between these two groups of subyearlings. We also compare the postrelease performance of 2008 releases of natural subyearlings to the postrelease performance of 2008 releases of surrogate and production subyearlings. The attributes of postrelease performance we compare include: detection timing, detection during implementation of summer spill, travel time, migrant size, and the joint probability of migration and survival. This objective provides the fisheries community with the empirical information needed to evaluate the efficacy of the surrogate release strategy and interpret patterns in future SARs from PIT-tagged surrogate and production subyearlings with different passage experiences. Based on the results of both objectives combined, we conclude that (1) juvenile life history varies markedly between the natural and production populations and (2) postrelease performance was much more similar between natural and surrogate subyearlings than between natural and production subyearlings. Smolt-to-adult return rates are not reported here, but will be presented in future reports written after workshops and input by federal, state, and tribal researchers.

INTRODUCTION

The Snake River upper reach, Snake River lower reach, Grande Ronde River, and Clearwater River are recognized as the four major spawning areas of Snake River Basin natural fall Chinook salmon *Oncorhynchus tshawytscha* upstream of Lower Granite Reservoir (Figure 1; ICTRT 2007). Though treated as one population, temperature during incubation and early rearing fosters life history diversity among the juveniles produced in these major spawning areas (Connor et al. 2002, 2003a). Young fall Chinook salmon in the Snake River upper reach emerge and begin seaward movement earliest in the year followed by fish from the Snake River lower reach, Grande Ronde River, and Clearwater River. Some fall Chinook salmon subyearlings discontinue active seaward movement, pass downstream in reservoirs throughout the Federal Columbia River Power System (FCRPS) from late fall to the following spring, and then enter the ocean as yearlings (Arnsberg and Statler 1995; Connor et al. 2002). This "reservoir-type" juvenile life history is important to adult returns and is more prevalent in the Clearwater River than in the Snake River (Arnsberg and Statler 1995; Connor et al. 2002, 2005; Marsh et al. 2007a).

Understanding how the Snake River Basin fall Chinook salmon population responds to dam passage "strategies" is critical to recovery of this population. We developed a method to evaluate the response to dam passage strategies that accommodates the diverse juvenile life history of Snake River Basin fall Chinook salmon juveniles (Marsh et al. 2007b). This method involves comparing smolt-to-adult return rates (SAR) from release upstream of Lower Granite Reservoir to adult return at Lower Granite Dam between two groups of subyearlings implanted with passive integrated transponder (PIT) tags (Prentice et al. 1990a). Both groups are released upstream of Lower Granite Reservoir, but they are treated differently at Lower Granite, Little Goose, Lower Monumental, and McNary dams (i.e., the collector dams) to represent two different dam passage strategies: (1) transportation with summer spill and (2) bypass with summer spill. Because SARs of anadromous salmonids generally do not exceed 2% at maximum, with a median range under good conditions of about 1% (J. Williams, NOAA Fisheries, personal communication), large numbers of fish are required to calculate precise ratios of SARs between treatment groups. Natural fall Chinook salmon subyearlings (hereafter, natural subyearlings) are not currently available in these numbers. Therefore, to compare SARS of different treatment groups for this study, our only option was to tag large numbers of hatchery-reared fall Chinook salmon subyearlings to supplement tagged natural fish.

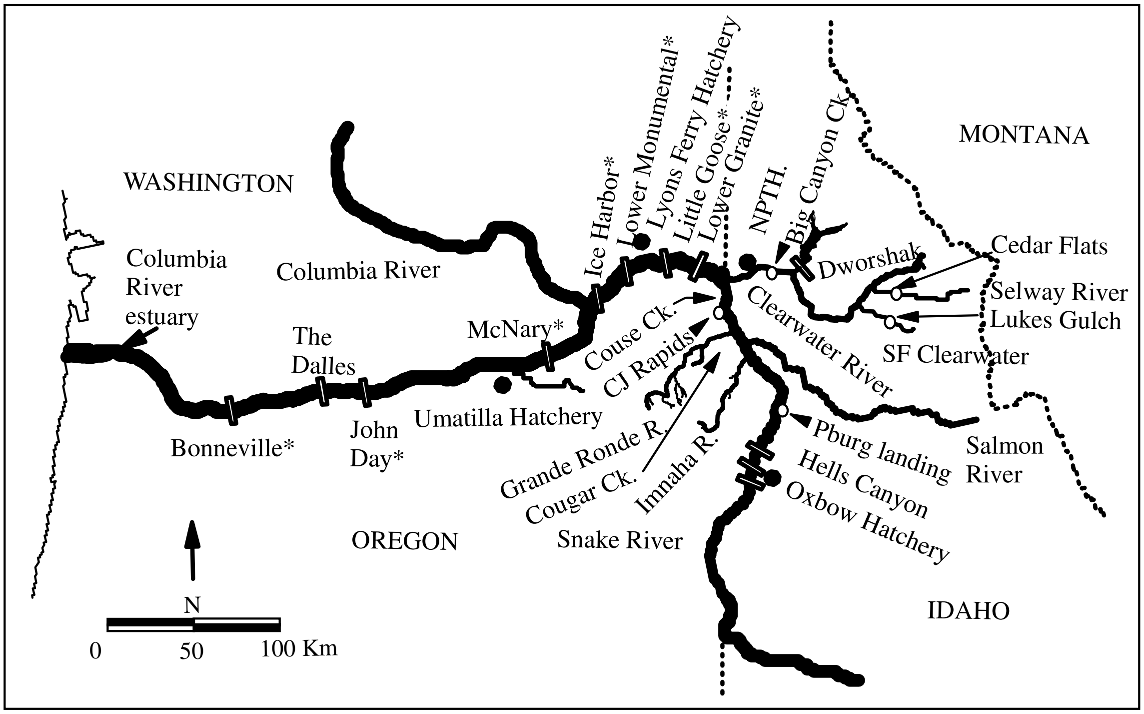

Figure 1.—The four major spawning areas of Snake River Basin fall Chinook salmon upstream of Lower Granite Reservoir include the Snake River upper reach (Hells Canyon Dam to Salmon River), Snake River lower reach (Salmon River to upper end of Lower Granite Reservoir), lower 83 km of the Grande Ronde River, and the lower 65 km of Clearwater River. Lyons Ferry Hatchery is the source the Snake River hatchery stock of fall Chinook salmon. The Nez Perce Tribal Hatchery (NPTH), Dworshak National Fish Hatchery (DNFH), Oxbow Hatchery, and Umatilla Hatchery culture the Lyons Ferry stock of fall Chinook salmon for production or research purposes. Release points of surrogate subyearlings include the mouths of Couse and Big Canyon creeks. Release points of production subyearlings include: (1) Hells Canyon Dam, (2) Pittsburg Landing acclimation facility, (3) the mouth of Cougar Creek, (4) Captain John Rapids acclimation facility, (5) the mouth of Couse Creek, (6) NPTH, (7) Big Canyon Creek acclimation facility, (8) Cedar Flats acclimation facility, and (9) Lukes Gulch acclimation facility. Lower Granite, Little Goose, Lower Monumental and McNary dams are collector dams, from which collected fish can be transported for release downstream of Bonneville Dam. Dams equipped with PIT-tag detection systems are indicated by an asterisk.

Surrogate and production rearing strategies are presently available for rearing large numbers of hatchery subyearlings. The surrogate rearing strategy involves slowing growth of excess Lyons Ferry Hatchery subyearlings to match the mean size of PIT-tagged natural subyearlings (70–75 mm; Connor et al. 2000) as closely as possible, while insuring that all of the surrogate subyearlings are large enough for tagging (i.e., 60-mm fork length). The surrogate rearing strategy also involves timing PIT tagging and release of the hatchery subyearlings to coincide with rearing and PIT tagging of natural subyearlings in the Snake and Clearwater rivers (e.g., Smith et al. 2003). The production rearing strategy is one of two routine strategies used to supplement production in the wild. It involves accelerating growth at Lyons Ferry Hatchery to achieve a target fork length of 90–95 mm fork length (Connor et al. 2004), sometimes followed by a few weeks of acclimation at sites along the Snake and Clearwater rivers (Figure 1). In contrast to surrogate subyearlings, the life history timing of natural fish is not considered when scheduling release dates of production subyearlings. Release dates of production subyearlings are based on factors such as seasonal flow levels, whether or not fish have grown to the 90–95 mm target size, and the availability of acclimation facilities. Not evaluated here is the other production strategy that rears fish to the yearling stage prior to release.

In the 1995 to 2000 migration years, we PIT-tagged natural, surrogate, and production subyearlings to study migrational behavior and survival, and to monitor and evaluate supplementation (e.g., Connor et al. 2002, 2003b, 2003c, 2004; Smith et al. 2003). Results indicated the migrational behavior and passage timing at dams was greater between natural subyearlings and surrogate subyearlings than between natural subyearlings and production subyearlings. Thus, we selected the surrogate rearing strategy to provide the necessary numbers of fish for calculating precise SAR ratios when designing and implementing our current passage strategy study. We made pilot and full-scale releases of surrogate subyearlings into the Snake and Clearwater rivers in 2005 and 2006, respectively. We will wait to report SARs from these releases until after we have complete returns of full-term adults (Marsh et al. 2007b).

We made a second full-scale release of PIT-tagged surrogate subyearlings and the first full-scale release of PIT-tagged production subyearlings in 2008 (Marsh et al. 2007b). Releasing production subyearlings has been suggested as a possible alternative for making inferences of the effects of passage experience (see definition below) on the natural population if surrogate fish were not available. The SARs from the 2008 production subyearling releases are not intended to represent SARs of natural subyearling, or to provide data for managing the river to increase the SARs of the natural population. As described in the consensus proposal (Marsh et al. 2007b), these releases were made to (1) calculate SARs for monitoring and evaluating supplementation and (2) understand the response of production subyearlings to dam passage "experiences" including transportation(T_0), bypass (C_1), and inriver migration without bypass (C_0).

The first objective of this report is to construct passage indices at Lower Granite Dam for the Snake River basin natural and production juveniles. This objective provides a simple illustration of the differences between these two groups of juveniles. Passage timing reflects diversity in juvenile life history (or the lack thereof) and is the cumulative product of rearing environment, growth, migration rate, migrational behavior, survival, and seasonal changes in the environment (e.g., Connor et al. 2000, 2002, 2003b,c, 2004). Further, differences observed between natural and production subyearlings from release to Lower Granite Dam persist and sometimes increase as fish pass downstream (Connor et al. 2008a,b). The second objective is to compare the postrelease performance of 2008 releases of natural subyearlings to the postrelease performance of 2008 releases of surrogate and production subyearlings. The attributes of postrelease performance we compare include: detection timing, detection during implementation of summer spill, travel time, migrant size, and the joint probability of migration and survival. This objective is completed separately for fish migrating from the Snake and Clearwater rivers. It provides the fisheries community with the empirical information needed to evaluate the efficacy of the surrogate release strategy and to interpret future patterns in the SARs of surrogate and production subyearlings.

METHODS

Fish Collection, Tagging, and Release

Natural Fall Chinook Salmon Subyearlings

Snake River.—We used a beach seine to capture subyearlings at sites in the free-flowing Snake River as described by Connor et al. (1998, 2002). Sampling began at the onset of fry emergence in late March and was conducted 3 d/week. A total of 15 permanent stations from rkm 241 to 361 (rkm 0 = Snake River mouth) were sampled almost every week. During 05/28–06/03, supplemental stations were sampled to increase the number of natural subyearlings PIT tagged. Sampling ended after the week of 07/13, when catch was near zero.

Origin (hatchery or natural) of unmarked (i.e., adipose fin not clipped) and untagged fish (i.e., no coded wire or PIT tag) was determined based primarily on pupil diameter and body shape. Natural fish had smaller pupils and were more robust than their hatchery counterparts. Each natural subyearling captured was anesthetized in a 3-mL MS-222 stock solution (100 g/L) per 19 L of water buffered with a sodium bicarbonate solution, measured to fork length (FL, in mm), weighed, and a tissue sample was collected for future genetic analyses. Natural subyearlings 60-mm and longer were implanted with a PIT tag and released at the collection site after a 15-min recovery period.

Clearwater River.—We used beach seines and rotary screw traps to capture subyearlings in the lower Clearwater River. Seining was conducted during 07/07–09/02 along the lower Clearwater River from rkm 3 to 62 (rkm 0 = Clearwater River mouth). Permanent sites were seined 5 d/wk when flow allowed. Supplemental sites were seined when time and flow allowed. Two sizes of beach seines fitted with 0.48 cm diameter mesh were used (30.5 × 1.8 m and 15.2 × 1.2 m). Both were fitted with weighted multistranded mud lines. The larger seine was set from a jet boat, and the smaller seine set by hand at less accessible and smaller sites. Two 2.4 m diameter rotary screw smolt traps were suspended from the Spalding railroad bridge along both the north and south shorelines at rkm 20 from 07/17 to 09/02 September. Catch neared zero the first week of September when beach seining and screw trapping were discontinued.

Origin (hatchery or natural) was determined as described for the Snake River. All subyearlings captured by all methods were placed in 18.9-L buckets and then in larger, aerated 114-L plastic holding bins. Subyearlings were anesthetized in a 3-mL MS-222 stock solution (100 g/L) per 19 L of water buffered with a sodium bicarbonate solution. All natural subyearlings were measured to the nearest 1.0 mm FL and weighed to the nearest 0.1 g. Tissue samples were collected (non-lethal upper caudal fin clip) from a random subsample of natural subyearlings for future genetic analyses. Natural subyearlings 60-mm FL and longer were implanted with PIT tags and released at the collection site after a 15-min recovery period.

Surrogate Fall Chinook Salmon Subyearlings

Snake River.—Acquisition of Lyons Ferry Hatchery fish for 2008 releases of Snake River surrogate subyearlings was coordinated under *U.S. v. Oregon*. In December 2007, roughly 215,000 eyed eggs were transferred from Lyons Ferry Hatchery to Umatilla Hatchery where they were incubated in well water. The incubation and feeding regimes were adjusted to produce 360 fish per pound (approximately 50-mm FL) for transport to Dworshak National Fish Hatchery on 04/07/ 2008. In March 2008, we randomly selected 60 of the Snake River surrogates at Umatilla Hatchery and examined them for *Renibacterium salmoninarum* antigen by enzyme-linked immunosorbent assay (ELISA). In addition, gill/kidney/spleen tissue was examined for viruses associated with infectious pancreatic necrosis, infectious hematopoietic necrosis, and viral hemorrhagic septicemia. The ELISA results were low (optical density less than 0.09), and viral tests were negative.

We transported the Snake River surrogates (roughly 212,000) to Dworshak National Fish Hatchery on 04/28/2008 in a truck equipped with a 7,500-L tank. Oxygen in the tank was kept near 100% saturation during the 4-h trip. Loading density was 0.1 kg/L, well below the recommended maximum of 0.24 kg/L for Chinook salmon (Piper et al. 1982). Upon arrival at Dworshak National Fish Hatchery, the subyearlings were piped from the tank into a 36-m^3 raceway supplied with 6.0°C water at approximately 1,136 L/min. The subyearlings were 133 fish per pound (about 64-mm FL). Starting fish density in the raceway was 20.0 kg/m^3. Fish were initially fed No. 2 crumb BioDiet starter. Feed size was increased to No. 1.5 BioDiet growth formula as the fish grew. Since the fish were larger than the target size of 360 fish per pound when they arrived at Dworshak National Fish Hatchery, we fed them a reduced ration of 1% of total body weight per day to prevent them from growing well beyond the 70–75 mm target FL for tagging and release scheduled in May and early June. The fish were split into a second and a third raceway as they grew. Each raceway was treated with 45 kg of coarse water softening salt (NaCl) immediately after fish were transferred, after weekly cleaning, splitting, and after crowding during tagging. There were no bacterial or viral epizootics during rearing.

The subyearlings were taken off feed 24–48 h before tagging. Final rearing density in the raceways before tagging ranged from 8.5 to 9.2 kg/m^3, well below densities reported to adversely affect adult returns of Chinook salmon (see Martin and Wertheimer 1989; Banks 1994; Ewing and Ewing 1995). Temperatures in the raceways during tagging ranged from 5.4 to 7.1°C. Tagging began on 5/19 and was conducted daily during three periods; 05/19–05/22, 05/26–05/30, and 06/2–06/5. These periods were selected to coincide with the historical period of peak beach seine catch of natural parr in the Snake River (Connor et al. 2002).

Each morning, the subyearlings in the raceway designated for tagging were crowded and then bucketed to a 1,893-L holding tank, which was supplied with raceway water and located inside a self-contained tagging trailer. Immediately before tagging, surrogates were transferred to a 379-L sink containing anesthetic water (45–50 mg/L MS-222). The water was recirculated through a 10-25 µm filter to remove particulate matter and then exposed to an ultraviolet light filter to prevent viral and bacterial infections. Surrogates smaller than about 60-mm FL or with obvious signs of disease or injury were rejected for tagging and piped back to an unoccupied raceway.

Biomark, Inc. was contracted to implant the subyearlings with 134.2-kHz ISO PIT tags (TX1400ST) using a modified syringe tipped with a 12-gauge hypodermic needle (Prentice et al. 1990a). Used needles were disinfected in a 70% alcohol solution for approximately 10 min before reuse. After tagging, each fish was measured (FL, mm) and each day a subsample of approximately 100 fish was wet weighed to the nearest 0.1 g. Fish were then piped to a transport truck equipped with a 1,800-L tank constantly supplied with fresh raceway water until tagging was completed.

After tagging was completed each day, we trucked the Snake River surrogates to the mouth of Couse Creek (253 km upstream from the Snake River mouth), Asotin Washington (19 km downstream of Couse Creek), or Billy Creek (12 km upstream from Couse Creek). Releases were made at Asotin on 05/20 and Billy Creek on 05/21 and 05/22 because flooding prevented road access to Couse Creek. During each 1.5–2-h trip to the release points, oxygen in the tank was kept near 100% saturation. Loading density was 0.02 kg/L and lower. Snake River surrogates were acclimated to ambient river temperature (range, 9.0–12.0°C) using a gasoline-powered water pump to gradually replace the raceway water in the tank with river water at a maximum rate of 2°C warming per hour.

The Snake River surrogates were released directly to the river via a flexible hose when tank temperature equaled river temperature, which generally occurred from late afternoon to near dusk. We monitored mortality throughout tagging and release. Pre-release mortality ranged from 0.0 to 0.12%. The tank was inspected for shed tags after fish were released. Shedding ranged from 0.0 to 0.07%.

Clearwater River.—Acquisition of Lyons Ferry Hatchery subyearlings for 2008 releases of Clearwater River surrogate subyearlings was coordinated under *U.S. v. Oregon*. In December 2007, roughly 116,000 eyed eggs were transferred from Lyons Ferry Hatchery to Umatilla Hatchery where they were incubated in chilled well water. The incubation and feeding regimes were adjusted to produce 700 fish per pound (approximately 45-mm FL) for transport to Dworshak National Fish Hatchery on 04/7/2008. In March 2008, we randomly selected 60 of the Clearwater River surrogates at Umatilla Hatchery and examined them for *Renibacterium salmoninarum* antigen by ELISA. In addition, gill/kidney/spleen tissue was examined for viruses associated with infectious pancreatic necrosis, infectious hematopoietic necrosis, and viral hemorrhagic septicemia. The ELISA results were low (optical density less than 0.09), and viral tests were negative.

We transported the fry from Umatilla Hatchery to Dworshak National Fish Hatchery on 04/09/2008 using a truck equipped with a 7,500-L tank. Oxygen in the tank was kept near 100% saturation during the 4-h trip. Loading density was 0.01 kg/L. Upon arrival at Dworshak National Fish Hatchery, the subyearlings were piped from the tank into a 36-m^3 raceway supplied with 6.0°C water at approximately 1,136 L/min. The number of fish per pound was 780 (about 40-mm FL). The initial rearing density was 4.5 kg/m^3 and the fish were split into three raceways as they grew. The subyearlings were fed, handled, tagged, and released as described for Snake River surrogates with the following eight exceptions. Clearwater River surrogate subyearlings were:

1) fed 2.75% of body weight per day;
2) reared to final densities of 2.3–3.0 kg/m^3;
3) tagged and released during 06/23–06/27, 06/29–07/03, and 07/07–07/11;
4) tagged at temperatures of 7.0–8.2°C;
5) transported for only 20-30 min to reach the release site at Leaning Pine boat launch (a.k.a., Kayler's Landing) 55 km upstream from the Clearwater River mouth;
6) acclimated and released at temperatures of 10.0–14.0°C;
7) maximum post-tagging mortality and shedding rates were 0.18 and 0.09%, respectively; and
8) approximately 5,000 50–59-mm FL were tagged with the 8.5 mm PIT tags.

We tagged surrogate subyearlings in 2008 with the 8.5-mm tags were to reduce the number of fish released unmarked and evaluate the feasibility of tagging with the smaller tags. The data collected on these fish are not analyzed in this report. See McCutcheon and Richmond (2008) for additional details and recommendations.

Production Fall Chinook Salmon Subyearlings

Production subyearlings that were PIT-tagged and released in 2008 were incubated, reared, and tagged at Lyons Ferry, Oxbow, Irrigon, Umatilla, and Nez Perce Tribal hatcheries (Figure 1). In 2008, the production subyearlings were PIT tagged several weeks before release. See McCutcheon and Richmond (2008) for details on tagging methods. The rearing and release locations varied as follows. Subyearlings reared at Lyons Ferry Hatchery were released at Pittsburg Landing and Captain John Rapids acclimation facilities along the Snake River, the mouth of Couse Creek along the Snake River, and Big Canyon Creek acclimation facility along the Clearwater River (Figure 1). Subyearlings reared at Oxbow Hatchery were directly released at Hells Canyon Dam (Figure 1). Subyearlings reared at Irrigon Hatchery were released at Hells Canyon Dam and into the Grande Ronde River at Cougar Creek (Figure 1). Subyearlings reared at Umatilla Hatchery were released at Hells Canyon Dam. Subyearlings reared at the Nez Perce Tribal Hatchery were transferred for release at the Cedar Flats and Lukes Gulch acclimation facilities located along the Selway and South Fork Clearwater rivers, respectively (Figure 1). See McCleod (2006) for additional information on the acclimation facilities.

Production subyearlings were PIT tagged with standard methods by both Biomark, Inc. and other agency/tribal staff. Representative weights were not taken. The number of production subyearlings that we PIT-tagged at given site was based on the percentage of the entire production subyearling population that was released at that site (Table A1).

Detection of PIT-Tagged Fish

At Lower Granite Dam, PIT-tagged fish that were collected by fish guidance screens were routed to the juvenile bypass system where they were detected in flumes equipped with PIT-tag systems (Prentice et al. 1990b). Fish were routed using automated slide gates that directed a fish based on its PIT-tag code (Marsh et al. 1999; Downing et al. 2001). Study fish designated for transport (50% for natural and surrogate subyearlings; 46% for production subyearlings) were routed in “monitor mode.” Fish routed in monitor mode were guided to raceways for eventual transport unless the raceways were at holding capacity or being serviced. Under these situations, which did not occur in 2008, the fish would be routed back to the river. Those fish designated for inriver migration (50% for natural and surrogate subyearlings; 54% for production subyearlings) were routed back to the river. The PIT-tagged subyearlings continued migration in the river if they were routed from the bypass system back to the river, if they passed Lower Granite Dam under submersible traveling screens and through turbines, or if they passed via the spillways. Those that survived downstream passage were potentially detected at Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville Dams. Fish were routed at Lower Granite, Little Goose, and McNary dams as described for Lower Granite Dam.

The PIT-tag detection systems at the dams are dewatered part of the year and PIT-tagged fish that pass the dams when the systems are dewatered are not detected. The PIT-tag detection systems were dewatered during the following periods:

1) Lower Granite Dam 12/13/2008–03/25/2009;

2) Little Goose Dam 11/01/2008–03/25/2009;

3) Lower Monumental Dam 12/18/2008–03/18/2009;

4) Ice Harbor Dam 01/11/2009–03/16/2009;

5) McNary Dam 11/19/2008–03/31/2009;

6) John Day Dam 12/02/2008–3/30/2009; and

7) Bonneville Dam 12/18/2008–02/24/2007.

To increase seasonal coverage of passage in 2008, the PIT-tag detections systems were supplied with water up an additional 42 days at Lower Granite Dam and 79 days at Lower Monumental Dam. The PIT-tag detection system at Ice Harbor Dam was supplied with water for an additional 22 days between 12/16/2008 to 01/11/2009 as a result of non-routine maintenance. We downloaded detection data collected at the dams from the PIT tag Information System (PTAGIS 2008).

Downstream Recapture of Juveniles

We used the separation-by-code system at Lower Granite Dam (e.g., Downing et al. 2001) to recapture a randomly designated sample of PIT-tagged Snake River natural, surrogate, and production subyearlings during summer 2008. We did not attempt to recapture Clearwater River natural subyearlings because relatively few are detected at Lower Granite Dam as subyearlings in most years (Arnsberg et al. 2009) and past efforts have led to a small sample sizes of recaptured fish.

Objective 1 Data Analyses

Passage Indices for Natural and Production Juveniles at Lower Granite Dam

To construct passage indices at Lower Granite Dam for the Snake River basin natural and production subyearlings, we analyzed the PIT-tag detection data collected jointly on Snake River and Clearwater River natural juveniles during migration years 2008 and 2009. In 2007, 63% of the redds counted upstream of Lower Granite Reservoir were counted in the Snake River and lower reaches of its tributaries not including the Clearwater River. The remaining 37% was counted in the Clearwater River in its tributaries. We calculated weights for the data collected in river to better represent passage of the natural population as a whole (Snake River data, 63% / 78% = 0.807; Clearwater River, 37% / 22% = 1.686). We then multiplied the daily number of detections made at Lower Granite Dam for Snake River and Clearwater River natural subyearlings by 0.807 and 1.686, respectively. The sum of the two products was taken as the daily number of detections for natural subyearlings. We analyzed the PIT-tag detection data collected jointly on Snake River and Clearwater River production juveniles to represent hatchery production subyearlings. To calculate the daily number of detections for production subyearlings, we summed the daily number of detections for six release groups of Snake River production subyearlings and three release groups of Clearwater River production subyearlings. Weighting was not necessary for production subyearlings because the release groups were PIT tagged in proportion to their release numbers.

Daily detection probability at dams depends on the efficiency of screens to intercept and divert fish entering turbine intakes into the juvenile collection system and the percentage of total river flow going into the turbines. Screen efficiency remains somewhat stable, but flow through the turbines varies considerably depending on the level of spill. Thus, spill percentage can greatly affect detection probably on a daily basis. Estimation of daily detection probability has been problematic (e.g., Connor et al. 2008b). We used the PIT-tag data and the methods of Cormack (1964) and Skalski et al. (1998) to estimate season-wide detection probability for two cohorts of Snake River natural subyearlings (cohorts are described later), two cohorts of Clearwater River natural subyearlings, the three weekly releases of Snake River surrogate subyearlings, the three weekly releases of Clearwater River surrogate subyearlings, the six release groups of Snake River production subyearlings, and the three release groups of Clearwater River production subyearlings. The U.S. Army Corps of Engineers measured percent spill at Lower Granite Dam during the period studied. We matched the daily value of percent spill to the 2008 detection date of each detected fish. For each of the above 19 aggregates of subyearlings, we calculated weighted mean percent spill (i.e., weighted by the number of detections made at a given percent spill). We natural $\log_e$-transformed the season-wide detection probabilities and fitted an ordinary least-squares regression model to predict detection probability from weighted mean percent spill (Figure 2). We input the observed percent spill value for every day of the 2008–2009 passage period studied into the regression model to predict daily detection probabilities and then back-transformed the predictions. To provide a daily passage index for a particular day, we divided the daily number of detections of natural subyearlings for that day by the predicted daily detection probability for that day. We summed: (1) the daily passage indices for the natural subyearlings to calculate weekly passage indices, (2) the weekly passage indices in 2008 to calculate a migration year 2008 passage index ($i\hat{}_{2008}$), (3) the weekly passage indices in 2009 to calculate a passage index for migration year 2009 ($i\hat{}_{2009}$), and (4) $i\hat{}_{2008}$ and $i\hat{}_{2009}$ to calculate the total passage index for natural subyearlings. We followed the same steps for production subyearlings.

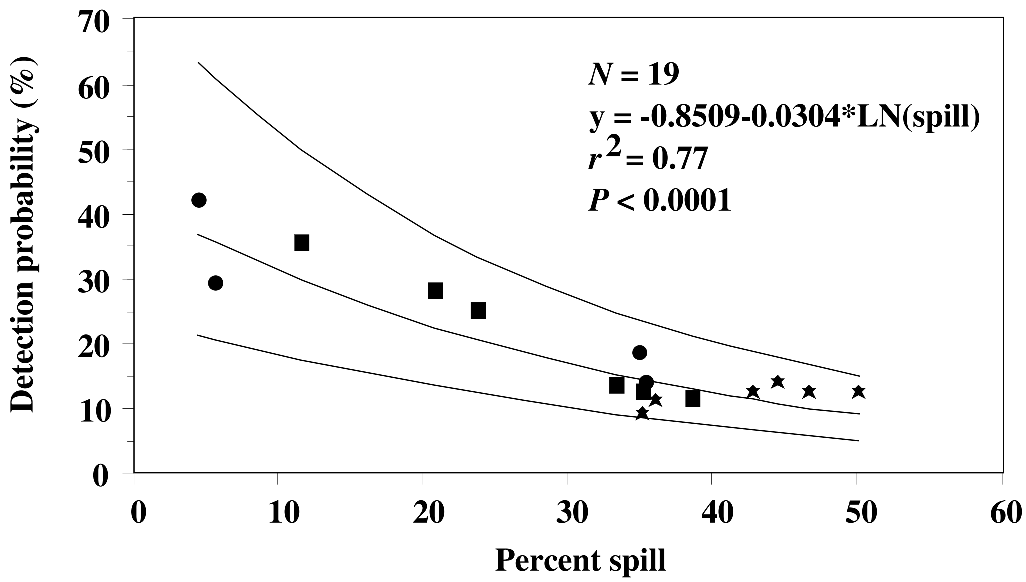

Figure 2.—The relation between season-wide detection probability (%) of four cohorts of natural subyearlings (circles), the six weekly releases of surrogate subyearlings (squares), and the nine release groups of production subyearlings (stars) and weighted mean percent spill (weighted based on number of detections) at Lower Granite Dam in 2008. The regression line is bounded by 95% prediction intervals.

Objective 2 Data Analyses

We calculated all of the postrelease attributes described hereafter separately by subyearling group and compared the attributes separately by river and dam. The dams included Lower Granite, Little Goose, and Lower Monumental. All statistical comparisons were made at alpha = 0.05. Given the present inability to derive accurate and unbiased estimates of detection probability for all of the subyearling groups at all three of the dams studied, we analyzed unexpanded detection data. We assumed that daily variation in percent spill was not the sole factor for differences observed between natural subyearlings and the two hatchery subyearling groups.

Detection Timing

To identify the maximum difference in detection timing throughout migration year 2008, we used the detection data collected from 05/06/2008 to the last day in 2008 the juvenile PIT-tag detection system at each dam was supplied with water (hereafter, migration year 2008 detections) to calculate cumulative detection distributions. We used a two-sample Kolmogorov-Smirnov test to evaluate differences in cumulative detection distributions between natural subyearlings and surrogate subyearlings and between natural subyearlings and production subyearlings. We reported Kolmogorov-Smirnov D_{max} values in percentage points, which were calculated as the maximum daily difference in cumulative detection distributions between natural and surrogate subyearlings and between natural and production subyearlings.

To evaluate differences in monthly detection, we used the migration year 2008 detection data to calculate the percentage of the detections made each month. For the Snake River analyses, we used chi-square analyses of 2 × 4 contingency tables (natural versus one of the other two subyearling groups; May, June, July, August–December [Lower Granite and Lower Monumental dams], August–November [Little Goose Dam]) to determine if there was significant difference in monthly detection percentages at each dam between natural and surrogate subyearlings and between natural and production subyearlings. If we found a significant difference with a 2 x 4 analysis, we used a chi-square analysis of 2 x 2 contingency table (natural versus one of the other two subyearling groups) to compare detection percentages for a given month. We analyzed monthly detection percentages for the Clearwater River subyearling groups as described above except the chi-square analysis began with a 2 x 7 contingency table (natural versus one of the other two surrogate subyearling groups; June, July, August, September, October, November, and December [Lower Granite and Lower Monumental dams only]) for comparing natural and surrogate subyearlings and a 2 x 8 contingency table (natural versus production subyearlings; May, June, July, August, September, October, November, and December) for comparing natural and production subyearlings..

To provide an index of the presence of yearling migrants in each group of subyearlings (noting that an uncountable number of fish passed the dams undetected when the PIT-tag detection systems were dewatered), we calculated the percentage of the total detections (i.e., migration years 2008 and 2009 combined) made in migration year 2009.

Detection Percentages during Spill Implementation

Summer spill was implemented at Lower Granite, Little Goose, and Lower Monumental Dams from 20 June to 31 August 2008. We calculated the percentage of the migration year 2008 detections made during summer spill implementation. For statistical comparisons between natural subyearlings and the other two groups of hatchery subyearlings, we used a chi-square analysis of 2×2 contingency table to determine if there was a difference in these detection percentages at each dam.

Our 2005 analysis on spill (Connor et al. 2008a) left some readers with the impression that many natural, surrogate, and production subyearlings were not being exposed to spill because it focused solely on summer spill. To provide the reader a more complete depiction of spill exposure, we calculated the percentage of 2008 migration year detections that occurred during spring spill.

Travel Time

For each subyearling detected at one or more of the three dams studied during migration year 2008, we calculated travel time as the number of days that elapsed between release and detection. Plots of residuals were skewed or bimodal even after transforming (natural logarithm) the travel times. Since we could not meet the normality assumption, we used a median test (Daniel 1978) to compare median travel time to each dam between natural subyearlings and the two groups of hatchery subyearlings.

Migrant Size

We used data collected on Snake River fish recaptured at Lower Granite Dam to characterize migrant size. The size characteristics analyzed included mean fork length (mm), mean weight (g) and mean condition factor K (weight divided by the cube of fork length multiplied by 10^5). We used a two-sample t test to determine if each of these indicators of size varied between natural subyearlings and the other two groups of subyearlings.

Joint Probability of Migration and Survival

Because of the reservoir-type juvenile life history, detection data did not always conform to the classic single-release recapture model described by Cormack (1964) and Skalski et al. (1998). Lowther and Skalski (1998) attempted to develop a model to deal with data of this nature. However, stopping the water supply to the PIT-tag detection systems at the dams during late fall and winter resulted in violation of a critical assumption of both the single release and Lowther and Skalski (1998) models.

One option for dealing with this situation was to use only detections of subyearlings made in migration year 2008. This results in data more likely to fit assumptions of the single-release model, but requires a reinterpretation of model parameters. By ignoring information collected on reservoir-type juveniles in migration year 2009, there is no distinction between cessation of “directed” or “active” migration and mortality during the year of release. Consequently, the parameter that is usually interpreted as the probability of survival must instead be interpreted as the joint probability of survival and migration in migration year 2008.

Natural fall Chinook salmon from the Snake River upper reach rarely exhibit the reservoir-type juvenile life history (e.g., 2% and less; Connor et al. 2002). Thus, we can assume that the majority of these fish pass during year *t* (e.g., migration year 2008) and few of these fish pass dams undetected from late fall to winter, when the PIT-tag detection systems are dewatered. Ignoring detections of reservoir-type juveniles in year *t* +1 (e.g., migration year 2009) after the PIT-tag detection systems are supplied with water, a typical single-release model "survival" estimate to the tailrace of Lower Granite Dam for upper Snake River reach fish might be 69%. In reality, this estimate is the product of the probability of migrating as a subyearling smolt and passing Lower Granite Dam in year *t* while the PIT-tag detection system is supplied with water (e.g., 98%) and the probability of surviving to the tailrace of Lower Granite Dam as a subyearling (e.g., 70%). That is, 69% = 98% × 70%. Thus, the estimate of the joint probability of migration and survival is only one percentage point lower than that of survival alone. Therefore, the joint probability estimate has relatively little bias as an estimate of actual survival probability alone.

However, natural fall Chinook salmon from the Clearwater River exhibit the reservoir-type juvenile life history more frequently (e.g., 6–85%; Connor et al. 2002) than those from the Snake River upstream of the Salmon River confluence. The prevalence of late fall passage, as well as empirical observations (Tiffan and Connor 2005), suggest that these reservoir-type juveniles commonly pass dams undetected during the winter, when PIT-tag detection systems are dewatered. Ignoring detections of reservoir-type juveniles that occur in the spring following release, a typical single-release model “survival” estimate to the tailrace of Lower Granite Dam for Clearwater fish might be 16%. Again, this quantity actually estimates the probability of migrating as a subyearling in year *t* while the PIT-tag detection system is supplied with water (e.g., 40%) and the probability of surviving to the tailrace of Lower Granite Dam (e.g., 40%; i.e., 40% × 40% = 16%). In this case, the joint probability estimate of migration and survival is 24 percentage points lower than actual survival probability alone.

We estimated the joint probability of migration and survival (± SE) from release to the tailrace of Lower Granite Dam, from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, from the tailrace of Little Goose Dam to the tailrace of

Lower Monumental Dam for the subgroups of subyearlings as described by Cormack (1964) and Skalski et al. (1998). We multiplied the SE for each estimate by 2 to calculate an approximate 95% confidence interval. The natural subyearling group was divided into subgroups by using the cohort approach (*n* = 2 per river; hereafter, cohorts 1 and 2; e.g., Connor et al. 2003b). For Snake and Clearwater River surrogate subyearlings, the subgroups were defined by tagging week (*n* = 3 in the Snake River; *n* = 3 in the Clearwater River). Production fish were kept in their original release groups by release location (*n* = 6 in the Snake River; *n* = 3 release in the Clearwater River).

We concluded that an estimate of the joint probability of migration and survival that exceeded 100% lacked accuracy, that had 95% C.I.s of ± 20% to ± 60% lacked precision, or that exceeded 100% and had wide confidence intervals lacked both accuracy and precision. Based on these criteria, we limited our 2008 Snake and Clearwater River analyses to comparisons made between estimates of the joint probability of migration and survival to the tailrace of Lower Granite Dam. We tested for significant differences between joint probability of migration and survival from release to the tailrace of Lower Granite Dam for the subgroups using likelihood ratio tests.

Overall Comparisons of Attributes

The preceding methods described formal statistical hypothesis tests made to compare postrelease attributes between natural and surrogate subyearlings and between natural and production subyearlings. We knew in advance that the outcome of these hypothesis tests would be of little use for determining if surrogate subyearlings were more similar to natural subyearlings than their hatchery counterparts cultured under the production rearing strategy. In some tests, we expected to reject the null hypotheses regardless of the magnitude of the actual differences because statistical power was high. In other tests, failure to find a significant difference did not rule out the existence of a biologically meaningful difference.

To provide a more informative series of comparisons, we calculated indices to determine which of the two hatchery subyearling groups was most similar to natural subyearlings. To calculate each index for a pair of groups, the higher value of an attribute was always divided by the lower value. For example, if median travel time to Lower Monumental Dam was 35 d for natural subyearlings and 31 d for surrogates, the index for natural versus surrogate comparison would be 1.1 (35/31). Likewise, if median travel time was 35 d for natural subyearlings and 14 d for production subyearlings the index for natural versus production subyearlings would be 2.5 (35/14). For this example, we would report a 1.1-fold or 10% difference between the mean travel times of natural and surrogate subyearlings and a 2.5-fold or 150% difference between the mean travel times of natural and production subyearlings. We would conclude that travel time was more similar between natural and surrogate subyearlings than between natural and production subyearlings.

Values used to calculate the indices varied by attribute. For cumulative detection date distributions, we used the cumulative percentage of the detections observed at D_{max}. For monthly detection percentages, we used the peak monthly detection percentage of natural subyearlings. When comparing D_{max} and peak monthly detection percentages between Clearwater River natural and production subyearlings, we sometimes had to analyze data other than the actual D_{max} or peak monthly detection percentage because the detection timing varied greatly between these two groups of subyearlings. For example, at Little Goose Dam D_{max} between Clearwater River natural and production subyearlings was observed on 07/24 when no natural subyearlings had been detected but 94.1% of the production subyearlings destined to be detected had already been detected. The peak month of detection at Lower Granite Dam for Clearwater River natural subyearlings was in November, but no Clearwater River production subyearlings were detected at this dam in November. So, we had to go back to September to find a month when both groups of subyearlings were detected. For age at migration, we divided the total number of fish detected in migration year 2008 by the total number detected in migration years 2008 and 2009 combined. We used the percentage of the migration year 2008 detections made during summer spill implementation to calculate the indices for this postrelease attribute. We explained similarity indices for travel time in the preceding paragraph. We calculated indices for comparing migrant size using fork length measurements taken at Lower Granite Dam for the Snake River comparisons. We calculated a total of six similarity indices for comparing the joint probability of migration and survival to the tailrace of Lower Granite Dam of the two Snake River natural subgroups and the three Snake River surrogate subgroups (i.e., cohort 1 versus weekly releases 1, 2, 3; cohort 2 versus weekly releases 1, 2, and 3). We then averaged the six indices to produce one index for final comparison. We followed the same procedure for comparisons made between Snake River natural and production subyearlings and for the Clearwater River subyearlings. We reported both the overall means and medians of the similarity indices for the comparisons made between natural and surrogate subyearlings and natural and production subyearlings. We reported the medians because some of the individual indices were very large. We focused the remainder of the analyses on the means, however, because the large differences in individual indices were biologically meaningful and needed to be given weight in our conclusions.

RESULTS

Fish Collection, Tagging, and Release

The number of subyearlings PIT tagged and released into the Snake River during 2008 was lowest for natural fish and highest for surrogates (Table 1). Natural subyearlings were released in the Snake River over a more protracted period than surrogate or production subyearlings. Forty-eight percent of the Snake River natural subyearling group was tagged and released during the 05/19–06/05 release period of the Snake River surrogate subyearlings. Tagged Snake River natural subyearlings averaged 8 mm smaller in fork length at tagging than surrogate subyearlings and 19–25 mm smaller than production subyearlings. Mean condition factor ($K \pm$ SD) at tagging was 1.11 ± 0.1 for natural subyearlings and 1.23 ± 0.1 for surrogate subyearlings.

The number of subyearlings PIT tagged and released into the Clearwater River in 2008 was lowest for natural fish and highest for surrogates (Table 1). Natural subyearlings were released in the Clearwater River over a more protracted period than surrogate or production subyearlings. Fifty percent of the Clearwater River natural subyearling group was tagged and released during the 06/23–07/11 release period of the Clearwater River surrogate subyearlings. Releases of production subyearlings were completed in one day at each release site. Natural Clearwater River subyearlings averaged 2 mm larger in fork length than surrogate subyearlings and 21–24 mm smaller than production subyearlings. Mean condition factor ($K \pm$ SD) at tagging was 1.09 ± 0.1 for natural subyearlings and 1.08 ± 0.1 for surrogate subyearlings.

Table 1.—The number (*N*), range of release dates, and mean fork length (mm ± SD) of PIT-tagged Snake River and Clearwater River natural, surrogate, and production subyearlings released in 2008. Production subyearlings were measured at tagging but not at release. We estimated fork length at release assuming the fish grew 0.5 mm/d between tagging and release.

Group	Subgroup	*N*	Release dates	Fork length
		Snake River		
Natural		3,902	04/22–07/16	71±10
Surrogates		201,845	05/19–06/05	79±7
Production	Hells Canyon Oxbow	15,469	05/06	
	Hells Canyon Umatilla	64,463	05/20	96±6
	Pittsburg Landing	31,834	05/27	90±5
	Captain John Rapids	39,152	05/28	91±6
	Couse Creek	16,054	05/28	92±6
	Cougar Creek	25,746	05/29	94±7
		Clearwater River		
Natural		1,097	07/07–08/29	71±12
Surrogates		105,444	06/23–07/11	69±5
Production	Big Canyon Creek	39,257	05/27	95±7
	Lukes Gulch	8,311	06/11	93±5
	Cedar Flats	8,233	06/12	92±5
		Total		
Natural		4,999		
Surrogates		307,289		
Production		233,077		

Objective 1: Passage Indices for Natural and Production Juveniles at Lower Granite Dam

Passage of natural juveniles at Lower Granite Dam began in spring 2008, peaked in summer 2008, continued throughout fall 2008, was still in progress when the PIT-tag detection system was dewatered in 2008 and watered back up in spring 2009 (Figure 3). Passage of production subyearlings was nearly complete by the end of summer 2008 (Figure 3). Of the natural subyearlings that made up the passage index for 2008 (i.e., $i\hat{}_{2008}$); 89.34% passed by 08/31/2008, 4.33% passed between 09/01/2008 and 11/01/2008, and 6.33% passed during the additional 42 days the PIT-tag detection system was supplied with water (11/02/2008–12/13/2008). These same percentages for production subyearlings were 99.98% by 08/31/2008, 0.01% between 09/01/2008 and 11/01/2008, and 0.01% during the additional 42 days the PIT-tag detection system was supplied with water. According to the total passage index (i.e., $I\hat{}$) for natural juveniles, 1.68% of the natural juveniles that passed Lower Granite Dam when the PIT-tag detection systems were supplied with water during 2008–2009 passed in 2009 (i.e., they were confirmed reservoir-type juveniles). According to the total passage index for production subyearlings, no production subyearlings that were released in 2008 passed Lower Granite Dam in 2009.

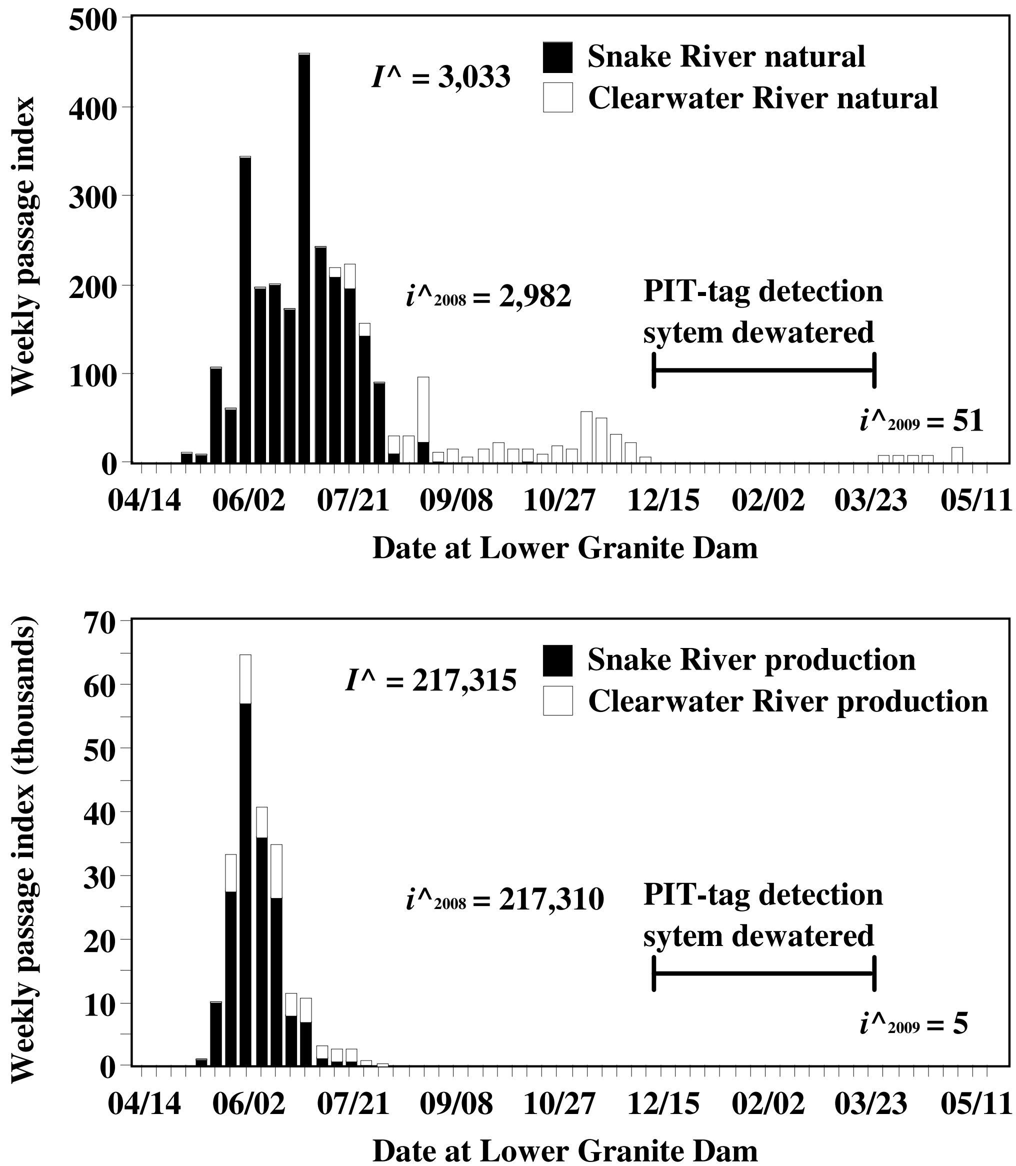

Figure 3.—Weekly passage indices at Lower Granite Dam during migration years 2008 and 2009 for Snake River and Clearwater River natural (top panel) and production fall Chinook salmon juveniles based on fish that were PIT tagged and released in 2008. The weekly indices were summed across migration years 2008 and 2009 (*I*^) and within each migration year 2008 ($i\^_{2008}$) and 2009 ($i\^_{2009}$).

Objective 2: Snake River Comparisons

Detection Timing

When the maximum difference in the migration year cumulative detection distributions (i.e., D_{max}) were observed at Lower Granite, Little Goose, and Lower Monumental dams, the detection of Snake River natural subyearlings was further from completion than the detection of surrogate subyearlings (Figure 4). On 07/05 when D_{max} (15.1 percentage points) was observed at Lower Granite Dam, 57.1% of the natural subyearlings destined to be detected had been detected compared to 72.2% for surrogate subyearlings. On 07/18 when D_{max} (9.0 percentage points) was observed at Little Goose Dam, 74.2% of the natural subyearlings destined to be detected had been detected compared to 83.2% for surrogate subyearlings. On 07/28 when D_{max} (11.7 percentage points) was observed at Lower Monumental Dam, 80.2% of the natural subyearlings destined to be detected had been detected compared to 91.9% for surrogate subyearlings.

D_{max} varied significantly between Snake River natural and surrogate subyearlings at Lower Granite ($P < 0.0001$) and Little Goose ($P = 0.0007$) dams, but not at Lower Monumental Dam ($P = 0.1$).

When D_{max} was observed at Lower Granite, Little Goose, and Lower Monumental dams, the detection of Snake River natural subyearlings was further from completion than the detection of production subyearlings (Figure 4). On 06/20 when D_{max} (57.1 percentage points) was observed at Lower Granite Dam, 24.6% of the natural subyearlings destined to be detected had been detected compared to 81.7% for production subyearlings. On 06/23 when D_{max} (68.5 percentage points) was observed at Little Goose Dam, 12.8% of the natural subyearlings destined to be detected had been detected compared to 81.3% for production subyearlings. On 06/22 when D_{max} (72.9 percentage points) was observed at Lower Monumental Dam, 12.9% of the natural subyearlings destined to be detected had been detected compared to 85.7% for production subyearlings.

D_{max} varied significantly between Snake River natural and production subyearlings at Lower Granite ($P < 0.0001$), Little Goose ($P < 0.0001$), and Lower Monumental ($P < 0.0001$) dams.

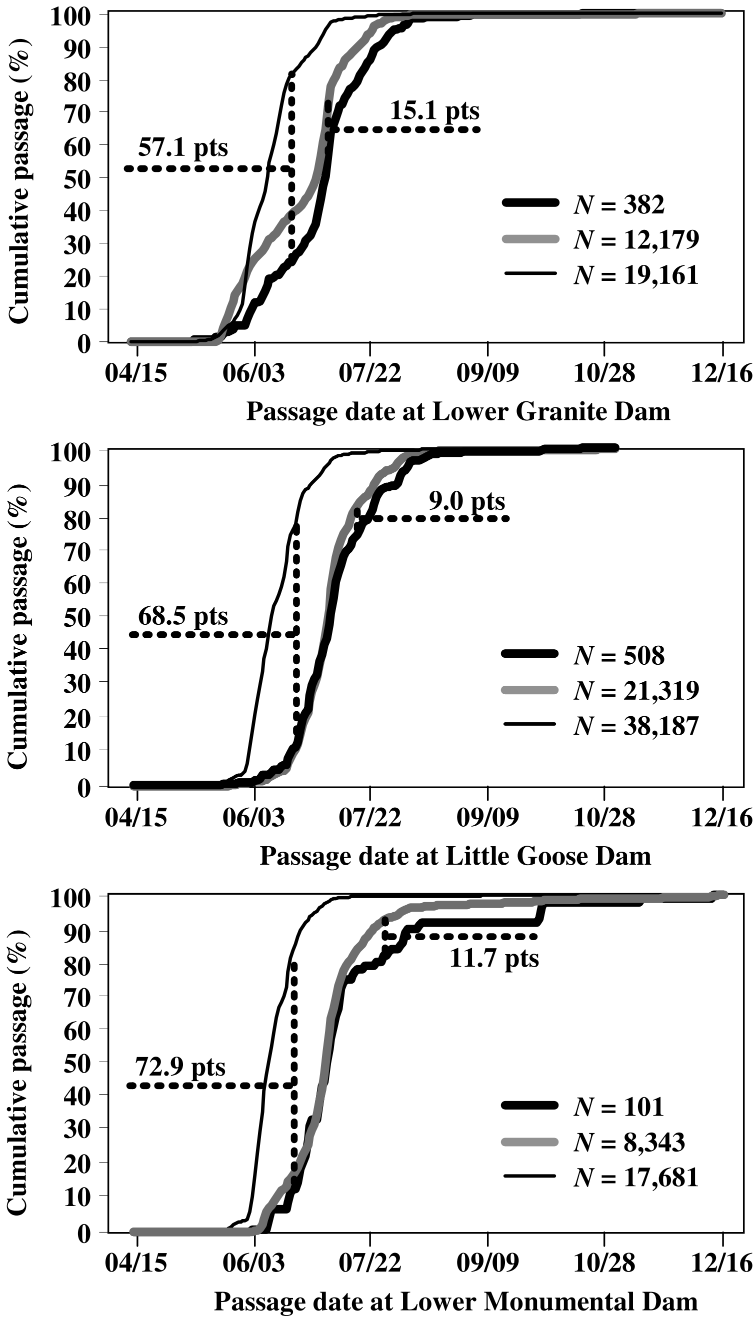

Figure 4.—Cumulative detection distributions at Lower Granite, Little Goose, and Lower Monumental dams for PIT-tagged Snake River natural (thick black line), surrogate (thick gray line), and production (thin black line) fall Chinook salmon subyearlings in migration year 2008. Percentage points (pts) and dotted lines indicate D_{max} values calculated as the maximum daily difference between cumulative detection distributions of natural and surrogate subyearlings, and between natural and production fall Chinook salmon subyearlings.

The inter-monthly trend in detections at Lower Granite, Little Goose, and Lower Monumental dams in migration year 2008 was similar between Snake River natural and surrogate subyearlings (Figure 5). July was the peak month of detection at all three dams for both groups of subyearlings. The July detection percentages for natural subyearlings were 58.4, 56.7, and 49.5% at Lower Granite, Little Goose, and Lower Monumental dams, respectively. The July detection percentages for surrogate subyearlings at these three dams were 49.5, 63.8, and 61.2%. Based on these results, the percentage point difference during the peak month of passage of natural subyearlings was 8.9 at Lower Granite Dam, 7.1 at Little Goose Dam, and 11.7 at Lower Monumental Dam.

There were significant differences in monthly detections in migration year 2008 between Snake River natural and surrogate subyearlings at all three dams (2 x 3 contingency tables; all P values < 0.0001). Monthly detections varied significantly between the two groups of subyearlings at Lower Granite Dam because of significant differences (2 x 2 contingency tables) in May ($P < 0.0001$), July ($P = 0.001$), and August–December ($P < 0.0001$). Monthly detections varied significantly between the two groups of subyearlings at Little Goose Dam because of significant differences in July ($P = 0.001$) and August–December ($P < 0.0001$). Monthly detections varied significantly between the two groups of subyearlings at Lower Monumental Dam because of significant differences in July ($P = 0.02$) and August–December ($P < 0.0001$). See Figure 5 to evaluate the actual differences in these monthly detections.

Monthly detections of both Snake River natural and production subyearlings during migration year 2008 increased from May to June at the three dams studied, but monthly detections of natural subyearlings continued to increase in July compared to the July decrease observed for production subyearlings (Figure 5). As noted above, the peak month of detection for natural subyearlings was July at the three dams studied. The July detection percentages for production subyearlings were 10.1, 9.0, and 5.0% at Lower Granite, Little Goose, and Lower Monumental dams, respectively. Based on these results, the percentage point difference during the peak month of passage of natural subyearlings was 48.3 at Lower Granite Dam, 47.7 at Little Goose Dam, and 44.5 at Lower Monumental Dam.

There were significant differences in monthly detections between Snake River natural and production subyearlings at all three dams in migration year 2008 (2 x 3 contingency tables; all P values < 0.0001). There were significant differences (all P values < 0.0002) in detection for every month except for May ($P = 0.06$) at Lower Monumental Dam. See Figure 5 to evaluate the actual differences in these monthly detections.

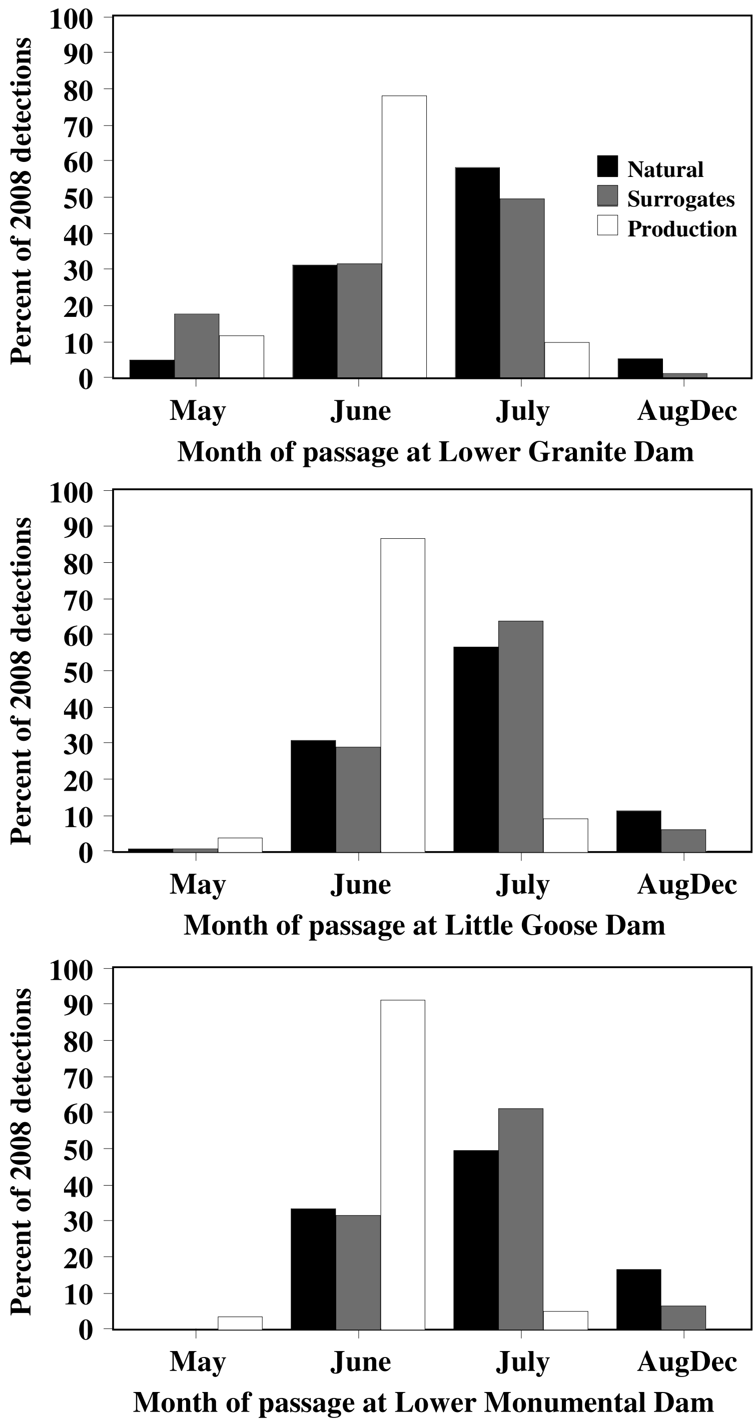

Figure 5.—Monthly percentages of the total detections made during migration year 2008 for PIT-tagged Snake River natural, surrogate, and production fall Chinook salmon subyearlings. The number of detections for each subyearling group is given in Figure 4.

All of the Snake River natural, surrogate, and production juveniles that were detected at Lower Granite Dam were detected in migration year 2008. Of the natural, surrogate and production juveniles detected during 2008–2009 at Little Goose Dam; 0.8% of natural, 0.1% of the surrogate, and 0.005% of the production juveniles were detected in 2009. These percentages at Lower Monumental Dam were 5.6% for natural juveniles, 0.6% for surrogate juveniles, and 0.03% for production juveniles.

Detection Percentages during Spill Implementation

The percentage of migration year 2008 detections made at Lower Granite Dam during summer spill implementation was 74.9% for Snake River natural subyearlings and 61.7% for Snake River surrogate subyearlings (Figure 6). The percentage of the migration year 2008 detections made at Little Goose Dam during summer spill implementation was 91.1% for natural subyearlings and 92.7% for surrogate subyearlings. The percentage of the migration year 2008 detections made at Lower Monumental Dam during summer spill implementation was 83.2% for natural subyearlings and 82.3% for surrogate subyearlings. Based on these results, there was a 0.08–13.2 percentage point difference between the migration year 2008 detection percentages of natural and surrogate subyearlings made during summer spill implementation.

The percentage of migration year 2008 detections made during summer spill implementation varied significantly between Snake River natural and surrogate subyearlings at Lower Granite Dam ($P < 0.0001$), but not at Little Goose ($P = 0.2$) or Lower Monumental ($P = 0.8$) dams.

The percentages of migration year 2008 detections of Snake River production subyearlings made at Lower Granite, Little Goose, and Lower Monumental dams during summer spill implementation were 19.6, 28.5, and 22.8%, respectively (Figure 6). Based on these results, there was a 55.3–62.7 percentage point difference between the migration year 2008 detection percentages of natural and production subyearlings made during summer spill implementation.

The percentage of the migration year 2008 detections made during implementation of summer spill was significantly higher for Snake River natural subyearlings than for Snake River production subyearlings at all three dams (all P values < 0.0001).

Nearly all (92.0–100%) of the Snake River natural, surrogate, and production subyearlings that were detected at Lower Granite, Little Goose, and Lower Monumental dams in migration year 2008 were detected during the implementation of spring and summer spill combined (Figure 6).

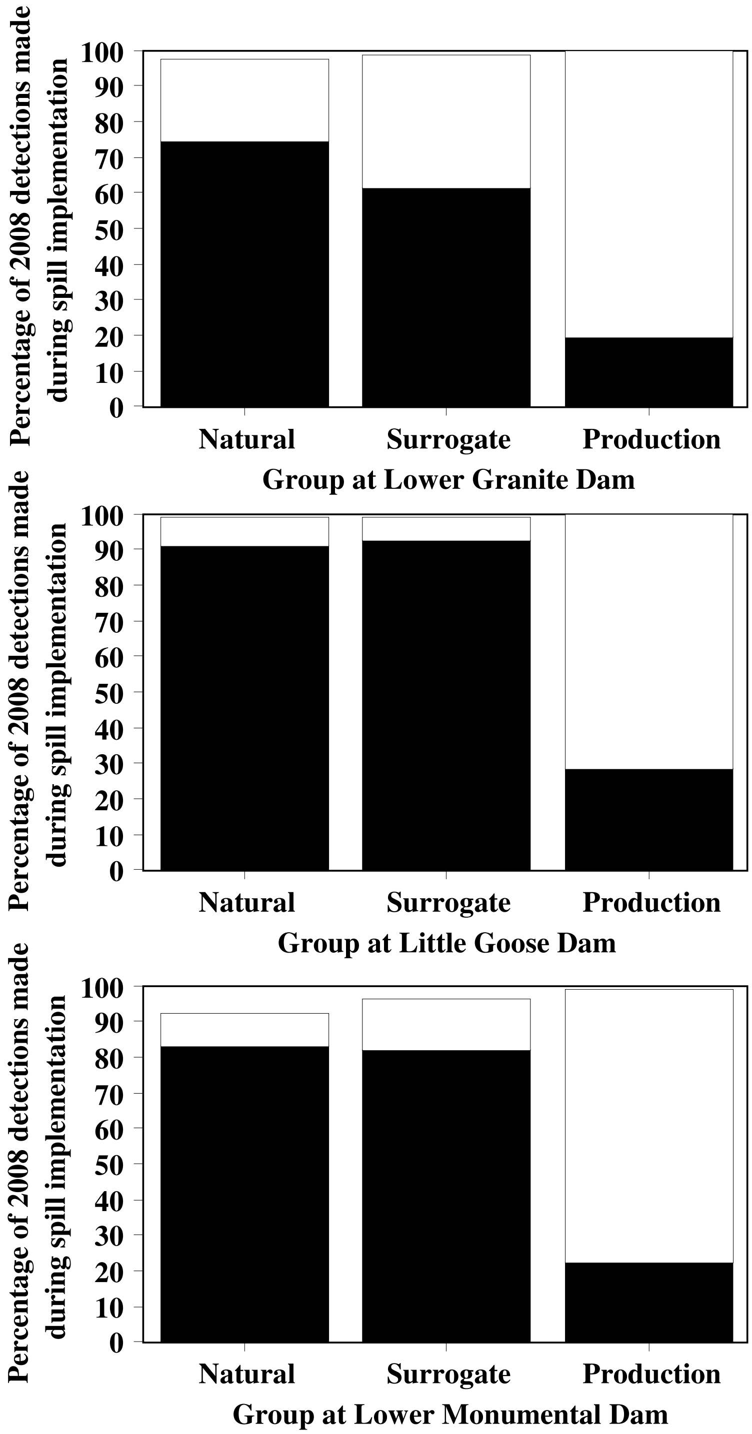

Figure 6.—The percentages of migration year 2008 detections of PIT-tagged Snake River natural, surrogate, and production fall Chinook salmon subyearlings made during summer (black portion of bar) or spring (white portion of bar) spill implementation at Lower Granite (top panel), Little Goose (middle panel), and Lower Monumental (bottom panel) dams. The number of detections for each subyearling group is given in Figure 4.

Travel Time

There was a 1-day difference in median travel time to Lower Granite Dam between Snake River natural and surrogate subyearlings in migration year 2008 (Table 2). The differences in median travel times between these two groups of subyearlings to Little Goose and Lower Monumental dams were 2 and 5 days, respectively.

Median travel time of Snake River natural and surrogate subyearlings to Lower Granite ($P = 0.1$) and Little Goose ($P = 0.3$) dams did not vary significantly in migration year 2008. The variation in median travel time to Lower Monumental Dam between these two groups of subyearlings was significant ($P = 0.004$).

There was a 15-day difference in median travel time to Lower Granite Dam between Snake River natural and production subyearlings in migration year 2008 (Table 2). There was a 19-day difference in travel times between these two groups of subyearlings to both Little Goose and Lower Monumental dams.

Median travel times of Snake River natural and production subyearlings to Lower Granite, Little Goose, and Lower Monumental dams varied significantly (all P values < 0.0001) in migration year 2008.

Table 2.—Median, minimum, and maximum travel time (days) of PIT-tagged Snake River natural, surrogate, and production fall Chinook salmon subyearlings from release to Lower Granite, Little Goose, and Lower Monumental dams in migration year 2008.

Dam	Group	*N*	Travel time		
			Median	Minimum	Maximum
Lower Granite	Natural	382	33	4	149
	Surrogate	12,179	34	1	199
	Production	19,161	18	2	173
Little Goose	Natural	508	41	6	144
	Surrogate	21,319	39	3	166
	Production	38,187	22	4	158
Lower Monumental	Natural	101	40	7	173
	Surrogate	8,343	35	2	211
	Production	17,681	21	1	200

Migrant Size

For Snake River fish recaptured at Lower Granite Dam in migration year 2008, natural subyearlings averaged 1 mm smaller in fork length than surrogates and 8 mm smaller in fork length than production subyearlings (Table 3). All subyearlings were robustly shaped (i.e., $K > 1.0$) when recaptured at Lower Granite Dam, but condition factor was higher for natural subyearlings than for surrogate and production subyearlings.

Mean fork length did not vary significantly ($P = 0.8$) between Snake River natural and surrogate subyearlings, but did vary significantly ($P = 0.01$) between natural and production subyearlings. Mean weight did not vary significantly ($P = 0.8$) between Snake River natural and surrogate subyearlings, but did vary significantly ($P = 0.04$) between natural and production subyearlings. Mean condition factor did not vary significantly ($P = 0.07$) between Snake River natural and surrogate subyearlings, but did vary significantly ($P = 0.003$) between natural and production subyearlings.

Table 3.—Mean fork length (mm ± SD), weight (g ± SD), and condition factor (*K* ± SD) of PIT-tagged Snake River natural, surrogate, and production fall Chinook salmon subyearlings released in migration year 2008 and recaptured at Lower Granite Dam in migration year 2008.

		Recapture dates				
Group	*N*	Min	Max	Fork length	Weight	*K*
Natural	22	05/29	11/20	98±22	10.7±5.9	1.11±0.07
Surrogate	54	05/22	07/21	99±15	11.0±4.8	1.06±0.10
Production	124	05/29	07/14	106±9	12.8±3.9	1.05±0.07

Joint Probability of Migration and Survival

The estimates of the joint probability of migration and survival of Snake River natural and surrogate subyearlings from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, and from the tailrace of Little Goose Dam to the tailrace of Lower Monumental Dam, were inaccurate, imprecise, or both inaccurate and imprecise (Table 4).

The joint probability of migration and survival to the tailrace of Lower Granite Dam averaged 60.5% for natural subyearlings and 62.0% for surrogate subyearlings (Table 4).

Natural cohort 1 had a significantly higher joint probability of migration and survival than surrogate release 3 and natural cohort 2 had a significantly lower joint probability of migration and survival than surrogate release 1 (Figure 7). No other comparisons between natural cohorts and surrogate releases were significant.

The joint probability of migration and survival to the tailrace of Lower Granite Dam averaged 60.5% for Snake River natural subyearlings and 78.5% for Snake River production subyearlings (Table 4).

The joint probability of migration and survival to the tailrace of Lower Granite Dam for all six production releases was significantly higher than for natural cohort 2 (Figure 7). None of the comparisons between natural cohort 1 and the six production release were significant.

Table 4.—The joint probability of migration and survival (% ± 95% C.I.) from release to the tailrace of Lower Granite Dam (LGR), from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam (LGS), from the tailrace of Little Goose Dam to the tailrace of Lower Monumental Dam (LMN), and from release to the tailrace of Lower Monumental Dam for PIT-tagged Snake River natural, surrogate, and production fall Chinook salmon subyearlings in migration year 2008. Estimates that lack accuracy, precision, or both are indicated in bold (see page 18 for criteria). The means (% ± 95% C.I.) of the individual estimates made for the period from release to the tailrace of Lower Granite Dam are also given.

		Joint probability of migration and survival		
Group	Subgroup	Release to LGR	LGR to LGS	LGS to LMN
Natural	Cohort 1	69.8±14.1	**82.6±23.50**	**77.5±38.2**
	Cohort 2	51.2±9.8	**101.2±30.92**	**117.0±90.2**
	Mean	60.5±18.4		
Surrogate	Release 1	68.1±3.3	71.1±4.6	79.8±7.9
	Release 2	61.2±2.9	78.4±5.3	89.1±10.9
	Release 3	56.8±2.9	82.5±6.30	90.9±14.1
	Mean	62.0±6.4		
Production	Hells Canyon (Oxbow)	78.8±3.8	91.1±5.5	93.0±6.4
	Hells Canyon (Umatilla)	81.0±2.2	91.0±3.3	94.6±4.4
	Pittsburg Landing	78.9±3.3	86.3±4.6	87.9±5.5
	Captain John Rapids	86.1±3.1	88.0±4.2	91.5±5.7
	Couse Creek	78.0±6.6	79.7±8.8	82.7±13.1
	Cougar Creek	68.0±5.9	76.1±8.3	77.9±11.5
	Mean	78.5±4.8		

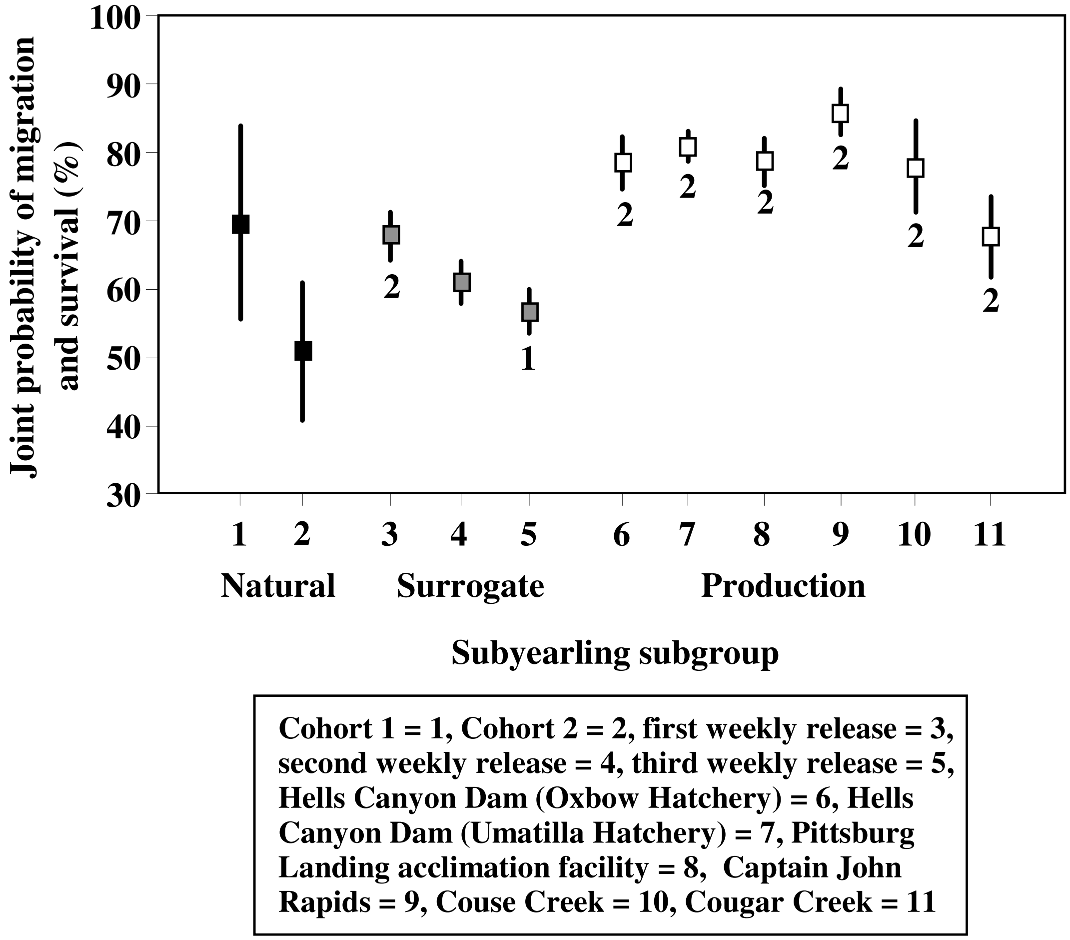

Figure 7.—The joint probability of migration and survival (± 95% C.I.) from release to the tailrace of Lower Granite Dam for subgroups of PIT-tagged Snake River natural, surrogate, and production fall Chinook salmon subyearlings in migration year 2008. A "1" below an estimate for a hatchery subgroup indicates a significant difference between the subgroup and the natural subyearling subgroup cohort 1; whereas, a "2" indicates a significant difference between the hatchery subgroup and the natural subyearling subgroup cohort 2.

Overall Comparison of Attributes

The indices for Snake River fish showed greater similarity between natural and surrogate subyearlings than between natural and production subyearlings (Table 5). The largest similarity index for natural and surrogate subyearlings (a 30% difference) was for cumulative detection at Lower Granite Dam. The largest similarity index for natural and production subyearlings was for peak monthly detection at Lower Monumental Dam (an 880% percent difference). Based on mean and median similarity indices calculated by dam, the level of similarity in the attributes of natural and surrogate subyearlings did not change as fish moved downstream (Lower Granite Dam, mean 1.1, median 1.1; Little Goose Dam, mean 1.1, median 1.1; Lower Monumental Dam, mean 1.1, median 1.1); whereas, the attributes of natural and production subyearlings became increasingly dissimilar as the fish moved downstream (Lower Granite Dam, mean 2.6, median 2.6; Little Goose Dam, mean 3.7, median 3.2; Lower Monumental Dam, mean 4.6, median 3.7). Overall, there was a 10% difference in the postrelease attributes of natural and surrogate subyearlings compared to a 250% difference between natural and production subyearlings.

Table 5.—Similarity indices (higher value divided by lower value of the attribute) for each comparison between 2008 releases of PIT-tagged Snake River natural and the two groups of hatchery fall Chinook salmon subyearlings. An index value of 1.0 would indicate no difference, while a value of 2.0 would indicate a two-fold difference. The attribute values are proportions except for migrant size (mm) and travel time (days). See page 19 for attribute descriptions.

Attribute	Attribute values		Similarity indices	Attribute values		Similarity indices
	Natural	Surrogates		Natural	Production	
Lower Granite Dam						
Cumulative detection	0.571	0.722	1.3	0.246	0.817	3.3
Peak monthly detection	0.584	0.495	1.2	0.584	0.101	5.8
2008 detection	1.000	1.000	1.0	1.000	1.000	1.0
Summer spill detection	0.749	0.617	1.2	0.749	0.196	3.8
Travel time	33	34	1.0	33	18	1.8
Migrant size	98	99	1.0	98	106	1.1
Migration/survival	See Table A2		1.2	See Table A2		1.3
Little Goose Dam						
Cumulative detection	0.742	0.832	1.1	0.128	0.813	6.4
Peak monthly detection	0.567	0.638	1.1	0.567	0.090	6.3
2008 detection	0.992	0.999	1.0	0.992	1.000	1.0
Summer spill detection	0.911	0.927	1.0	0.911	0.285	3.2
Travel time	41	39	1.1	41	22	1.9
Lower Monumental Dam						
Cumulative detection	0.802	0.919	1.1	0.129	0.857	6.7
Peak monthly detection	0.495	0.612	1.2	0.495	0.050	9.8
2008 detection	0.944	0.994	1.1	0.944	1.000	1.1
Summer spill detection	0.832	0.823	1.0	0.832	0.228	3.7
Travel time	40	35	1.1	40	21	1.9
Overall mean			1.1			3.5
Overall median			1.1			3.2

Objective 2: Clearwater River Comparisons

Detection Timing

When the maximum differences in the migration year 2008 cumulative detection distributions (i.e., D_{max}) were observed, the detection of Clearwater River natural subyearlings was further from completion than the detection of surrogate subyearlings at Lower Granite and Lower Monumental dams but closer to completion at Little Goose Dam (Figure 8). On 10/03 when D_{max} (36.3 percentage points) was observed at Lower Granite Dam, 28.4% of the natural subyearlings destined to be detected had been detected compared to 64.8% for surrogate subyearlings. On 10/03 when D_{max} (12.4 percentage points) was observed at Little Goose Dam, 80.0% of the natural subyearlings destined to be detected had been detected compared to 67.6% for surrogate subyearlings. On 11/28 when D_{max} (30.8 percentage points) was observed at Lower Monumental Dam, 10.7% of the natural subyearlings destined to be detected had been detected compared to 41.5% for surrogate subyearlings.

D_{max} varied significantly between Clearwater River natural and surrogate subyearlings at Lower Granite ($P < 0.0001$) and Lower Monumental ($P = 0.01$) dams, but not at Little Goose Dam ($P = 0.8$).

When D_{max} was observed at Lower Granite, Little Goose, and Lower Monumental dams, the detection of Clearwater River natural subyearlings was just beginning or had yet to begin; whereas, the detection of production subyearlings was nearly complete (Figure 8). On 08/12 when D_{max} (95.8 percentage points) was observed at Lower Granite Dam, 3.7% of the natural subyearlings destined to be detected had been detected compared to 99.4% for production subyearlings. On 07/24 when D_{max} (94.1 percentage points) was observed at Little Goose Dam, none of the natural subyearlings destined to be detected had been detected compared to 94.1% for production subyearlings. On 08/17 when D_{max} (98.7 percentage points) was observed at Lower Monumental Dam, none of the natural subyearlings destined to be detected had been detected compared to 98.7% for production subyearlings.

D_{max} varied significantly between Clearwater River natural and production subyearlings at Lower Granite ($P < 0.0001$), Little Goose ($P < 0.0001$), and Lower Monumental ($P < 0.0001$) dams.

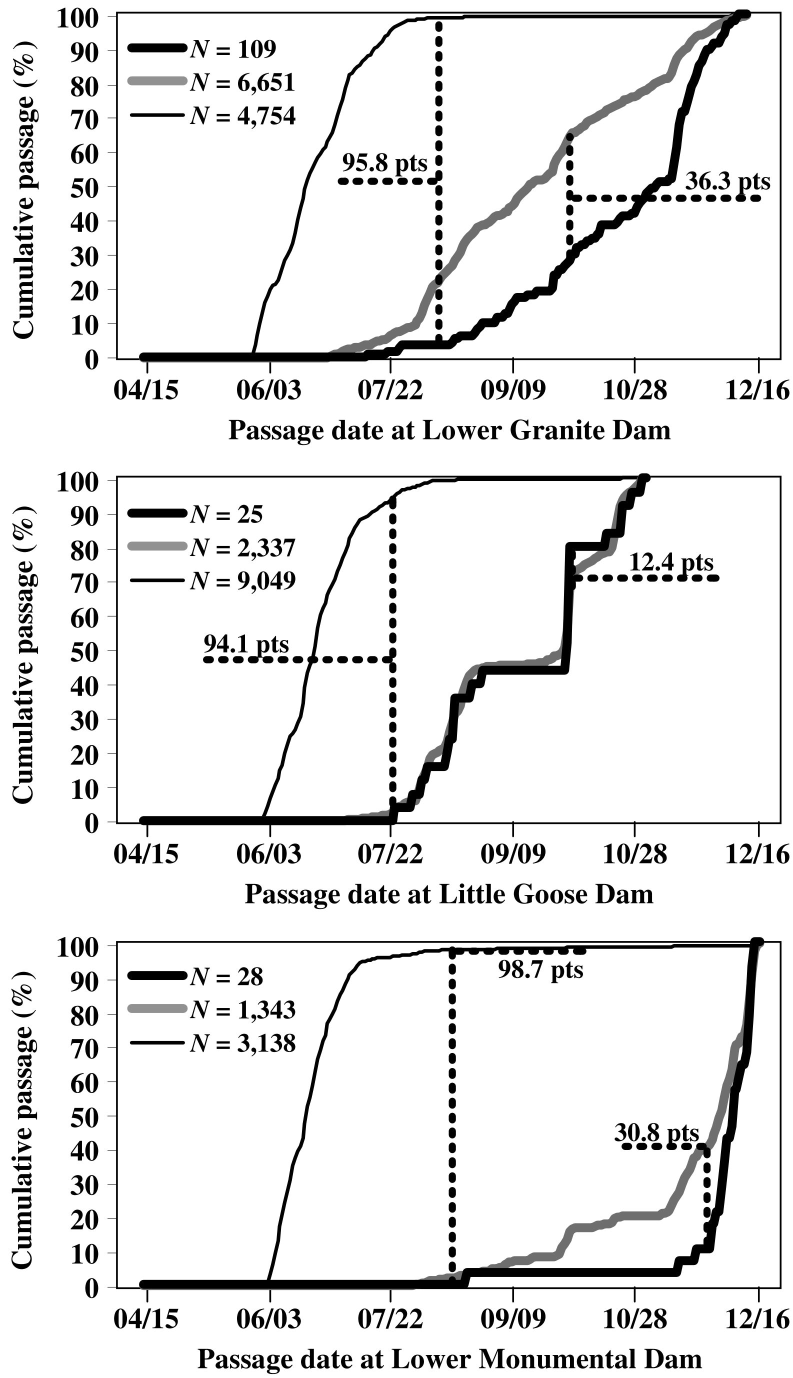

Figure 8.—Cumulative detection distributions at Lower Granite, Little Goose, and Lower Monumental dams for PIT-tagged Clearwater River natural (thick black line), surrogate (thick gray line), and production (thin black line) fall Chinook salmon subyearlings in migration year 2008. Percentage points (pts) and dotted lines indicate D_{max} values calculated as the maximum daily difference between cumulative detection distributions of natural and surrogate subyearlings, and between natural and production subyearlings.

The inter-monthly trend in detections at Lower Granite Dam in migration year 2008 from June through August was similar between Clearwater River natural and surrogate subyearlings, but varied thereafter (Figure 9). The inter-monthly trend in detections at Little Goose and Lower Monumental dams was similar between these two groups of subyearlings (Figure 9). The peak months of detection for natural subyearlings were November (19.3%), October (52%), and December (82.1%) at Lower Granite, Little Goose, and Lower Monumental dams, respectively. The detection percentages for surrogate subyearlings during these three months and dams were 17.1, 49.6, and 55.6%. Based on these results, the percentage point difference during the peak month of passage of natural subyearlings was 27.3 at Lower Granite Dam, 2.4 at Little Goose Dam, and 26.5 at Lower Monumental Dam.

There were significant differences in monthly detections in migration year 2008 between Clearwater River natural and surrogate subyearlings at Lower Granite Dam (2 x 7 contingency table; P value < 0.0001), but not at Little Goose (P = 0.7) or Lower Monumental (P = 0.2) dams. Monthly detections varied significantly between the two groups of subyearlings at Lower Granite Dam because of significant differences (2 x 2 contingency tables) in August (P < 0.0001), November (P < 0.0001), and December (P = 0.003). See Figure 9 to evaluate the actual differences in these monthly detections.

The inter-monthly trends in detections varied between Clearwater River natural and production subyearlings during migration year 2008 at Lower Granite Little Goose and Lower Monumental dams (Figure 9). As noted above, the peak months of detection for natural subyearlings were November (19.3%), October (52%), and December (82.1%) at Lower Granite, Little Goose, and Lower Monumental dams, respectively. The detection percentages for production subyearlings during these three months at these three dams were 0, 0.1, and 0.1%. Based on these results, the percentage point difference during the peak month of passage of natural subyearlings was 46.8 at Lower Granite Dam, 51.9 at Little Goose Dam, and 82.0 at Lower Monumental Dam.

There were significant differences in monthly detections between Clearwater River natural and production subyearlings at all three dams studied (2 x 7 contingency tables; all P values < 0.0001) during every month (2 x 2 contingency tables; largest P value = 0.02) except when few natural or production fish were detected in May (P = 0.9) and September (P = 0.9) at Little Goose Dam and May (P = 0.9), August (P = 0.4), September (P = 0.8), and October (P = 0.7) at Lower Monumental Dam. See Figure 9 to evaluate the actual differences in these monthly detections.

Of the Clearwater River natural, surrogate and production juveniles detected during 2008–2009 at Lower Granite Dam; 5.2% of natural, 1.3 of the surrogate, and 0.02% of the production juveniles were detected in 2009. These percentages at Little Goose Dam were 31.6% for natural juveniles, 18.2% for surrogate juveniles, and 0.03% for production juveniles. At Lower Monumental Dam, they were 44.0% for natural juveniles, 35.6% for surrogate juveniles, and 0.3% for production juveniles.

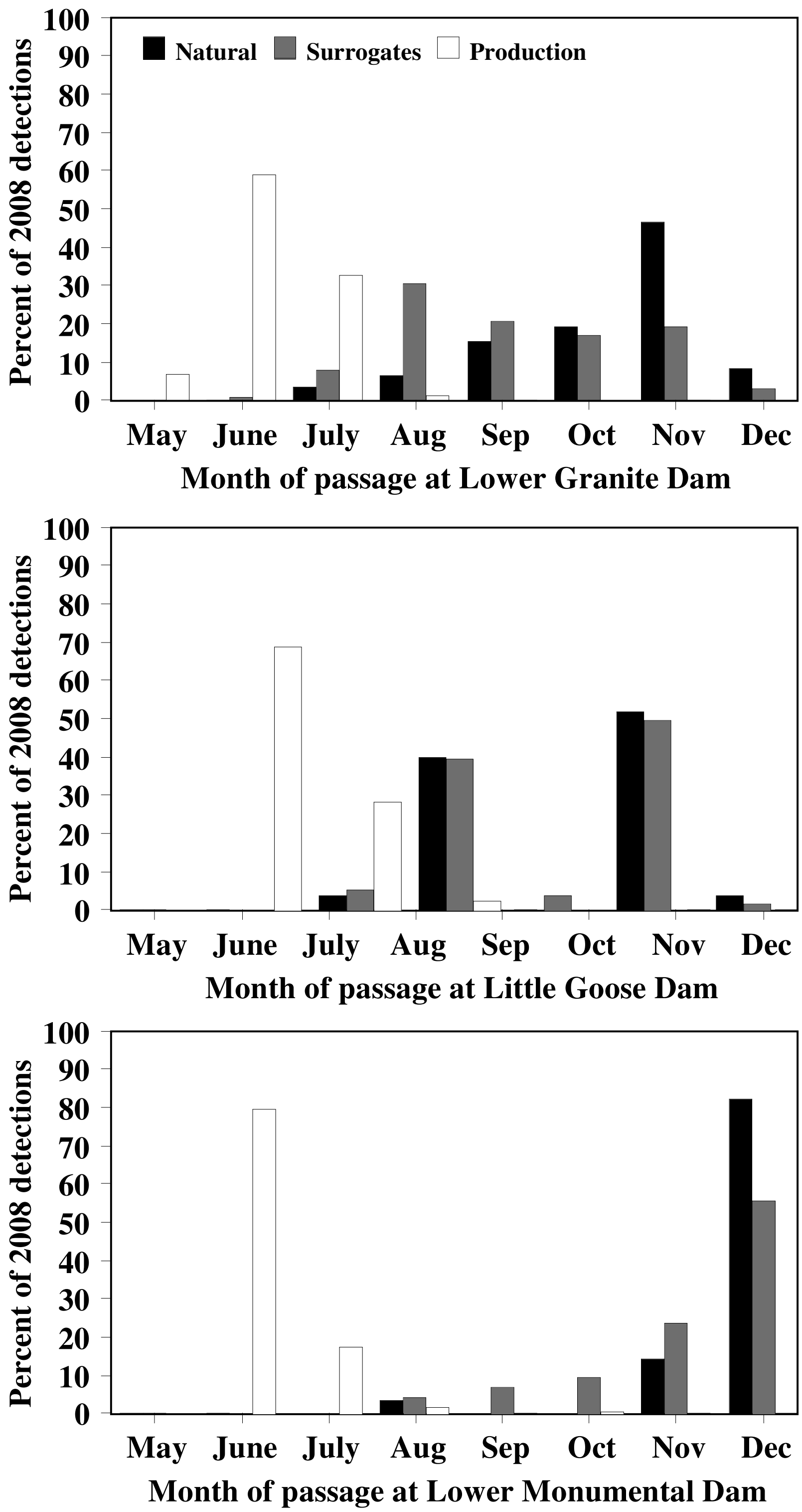

Figure 9.—Monthly percentages of the total detections in migration year 2008 for PIT-tagged Clearwater River natural, surrogate, and production fall Chinook salmon subyearlings. The number of detections for each subyearling group is given in Figure 8.

Detection Percentages during Spill Implementation

The percentage of the migration year 2008 detections made at Lower Granite Dam during summer spill implementation was 10.1% for Clearwater River natural subyearlings and 39.4% for Clearwater River surrogate subyearlings (Figure 10). The percentage of the migration year 2008 detections made at Little Goose Dam during summer spill implementation was 44.0% for natural subyearlings and 45.0% for surrogate subyearlings. The percentage of the migration year 2008 detections made at Lower Monumental Dam during summer spill implementation was 3.6% for natural subyearlings and 4.4% for surrogate subyearlings. Based on these results, there was a 0.08–29.3 percentage point difference between the migration year 2008 detection percentages of natural and surrogate subyearlings made during summer spill implementation.

The percentage of the migration year 2008 detections made during summer spill implementation varied significantly between Clearwater River natural and surrogate subyearlings at Lower Granite Dam ($P < 0.0001$), but not at Little Goose ($P = 0.9$) or Lower Monumental ($P = 0.8$) dams.

The percentages of the migration year 2008 detections of Clearwater River production subyearlings made at Lower Granite, Little Goose, and Lower Monumental dams during summer spill implementation were 50.2, 60.6, and 50.8%, respectively. Based on these results, there was a 16.6–47.3 percentage point difference between the migration year 2008 detection percentages of natural and production subyearlings made during summer spill implementation.

The percentage of the migration year 2008 detections made during implementation of summer spill was significantly lower for Clearwater River natural subyearlings than for Clearwater River production subyearlings at Lower Granite and Lower Monumental dams (both P values < 0.0001), but not at Little Goose Dam ($P = 0.1$).

None of the Clearwater River natural and surrogate subyearlings were detected at the three dams studied during the implementation of spring spill compared to 39.2–49.6% for Clearwater River production subyearlings (Figure 10).

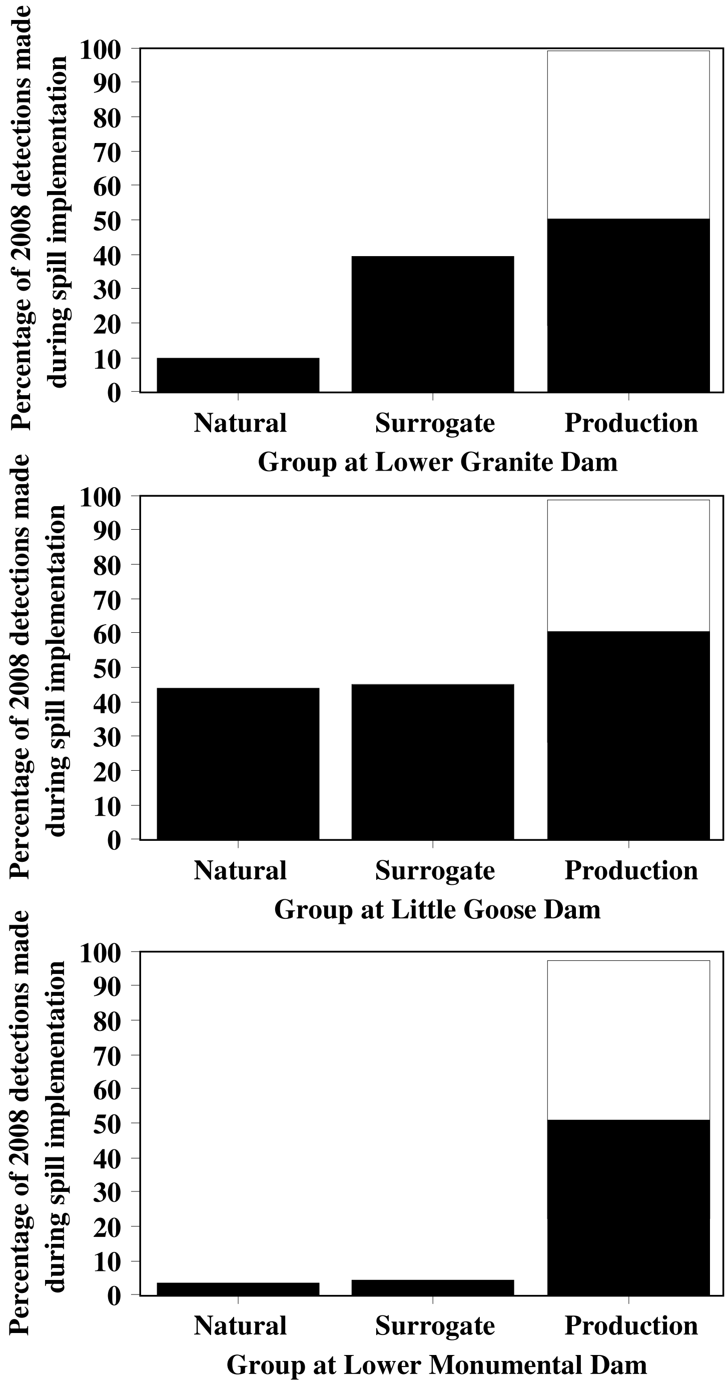

Figure 10.—The percentages of migration year 2008 detections of PIT-tagged Clearwater River natural, surrogate, and production fall Chinook salmon subyearlings made during summer (black portion of bar) or spring (white portion of bar) spill implementation at Lower Granite (top panel), Little Goose (middle panel), and Lower Monumental (bottom panel) dams. The number of detections for each subyearling group is given in Figure 8.

Travel Time

There was a 29-day difference in median travel time to Lower Granite Dam between Clearwater River natural and surrogate subyearlings in migration year 2008 (Table 6). The differences in travel times between these two groups of subyearlings to Little Goose and Lower Monumental dams were 14 and 2 days, respectively.

Median travel time of Clearwater River natural and surrogate subyearlings to Lower Granite ($P < 0.0001$) and Little Goose ($P = 0.03$) dams varied significantly in migration year 2008. Median travel time to Lower Monumental Dam between these two groups of subyearlings did not vary significantly ($P = 0.1$).

There was a 85-day difference in median travel time to Lower Granite Dam between Clearwater River natural and production subyearlings in migration year 2008 (Table 6). The differences in travel times between these two groups of subyearlings to Little Goose and Lower Monumental dams were 47 and 127 days, respectively.

Median travel time of Clearwater River natural and production subyearlings to Lower Granite, Little Goose, and Lower Monumental dams varied significantly (all P values < 0.0001) in migration year 2008.

Table 6.—Median, minimum, and maximum travel time of PIT-tagged Clearwater River natural, surrogate, and production fall Chinook salmon subyearlings from release to Lower Granite, Little Goose, and Lower Monumental dams in migration year 2008.

			Travel time		
Dam	Group	*N*	Median	Minimum	Maximum
Lower Granite	Natural	109	106	5	151
	Surrogate	6,651	77	2	173
	Production	4,754	21	2	199
Little Goose	Natural	25	71	11	107
	Surrogate	2,337	85	7	130
	Production	9,049	24	3	161
Lower Monumental	Natural	28	149	43	159
	Surrogate	1,343	151	11	177
	Production	3,138	22	1	205

Joint Probability of Migration and Survival

The estimates of the joint probability of migration and survival of Clearwater River natural subyearlings from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, and from the tailrace of Little Goose Dam to the tailrace of Lower Monumental Dam, were inaccurate, imprecise, or both inaccurate and imprecise (Table 7). Inaccuracy and imprecision were also noted in the estimates from the tailrace of Little Goose Dam to the tailrace of Lower Monumental Dam for all three surrogate releases and the production releases made from Cedar Flats.

The joint probability of migration and survival to the tailrace of Lower Granite Dam averaged 29.7% for natural subyearlings and 21.2% for surrogate subyearlings (Table 7).

Natural cohort 1 had a significantly higher joint probability of migration and survival than surrogate releases 2 and 3 and natural cohort 2 had a significantly higher joint probability of migration and survival than surrogate release 3 (Figure 11). No other comparisons between natural cohorts and surrogate releases were significant.

The joint probability of migration and survival to the tailrace of Lower Granite Dam averaged 29.7% for Clearwater River natural subyearlings and 76.3% for Clearwater River production subyearlings (Table 7).

The joint probability of migration and survival to the tailrace of Lower Granite Dam for all three production releases was significantly higher than for natural cohorts 1 and 2 (Figure 11).

Table 7.—The joint probability of migration and survival (% ± 95% C.I.) from release to the tailrace of Lower Granite Dam (LGR), from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam (LGS), from the tailrace of Little Goose Dam to the tailrace of Lower Monumental Dam (LMN), and from release to the tailrace of Lower Monumental Dam for PIT-tagged Clearwater River natural, surrogate, and production fall Chinook salmon subyearlings in migration year 2008. Estimates that lack accuracy, precision, or both are indicated in bold (see page 18 for criteria). The means (% ± 95% C.I.) of the individual estimates made for the period from release to the tailrace of Lower Granite Dam are also given.

		Joint probability of migration and survival		
Group	Subgroup	Release to LGR	LGR to LGS	LGS to LMN
Natural	Cohort 1	32.7±12.6	**260.0±490.3**	**17.4±34.8**
	Cohort 2	26.7±9.5	**73.2±71.0**	**50.5±68.2**
	Mean	29.7± 6.0		
Surrogate	Release 1	23.3±2.3	45.0±7.7	**122.3±47.4**
	Release 2	21.8±2.0	41.8±6.7	**137.7±58.5**
	Release 3	18.7±1.5	51.1±10.4	**165.6±114.0**
	Mean	21.2±2.6		
Production	Big Canyon Creek	83.7±4.7	81.0±5.7	90.7±8.0
	Lukes Gulch	74.7±8.4	85.8±13.1	79.9±18.0
	Cedar Flats	70.4±10.7	70.2±14.1	**95.4±31.5**
	Mean	76.3±7.8		

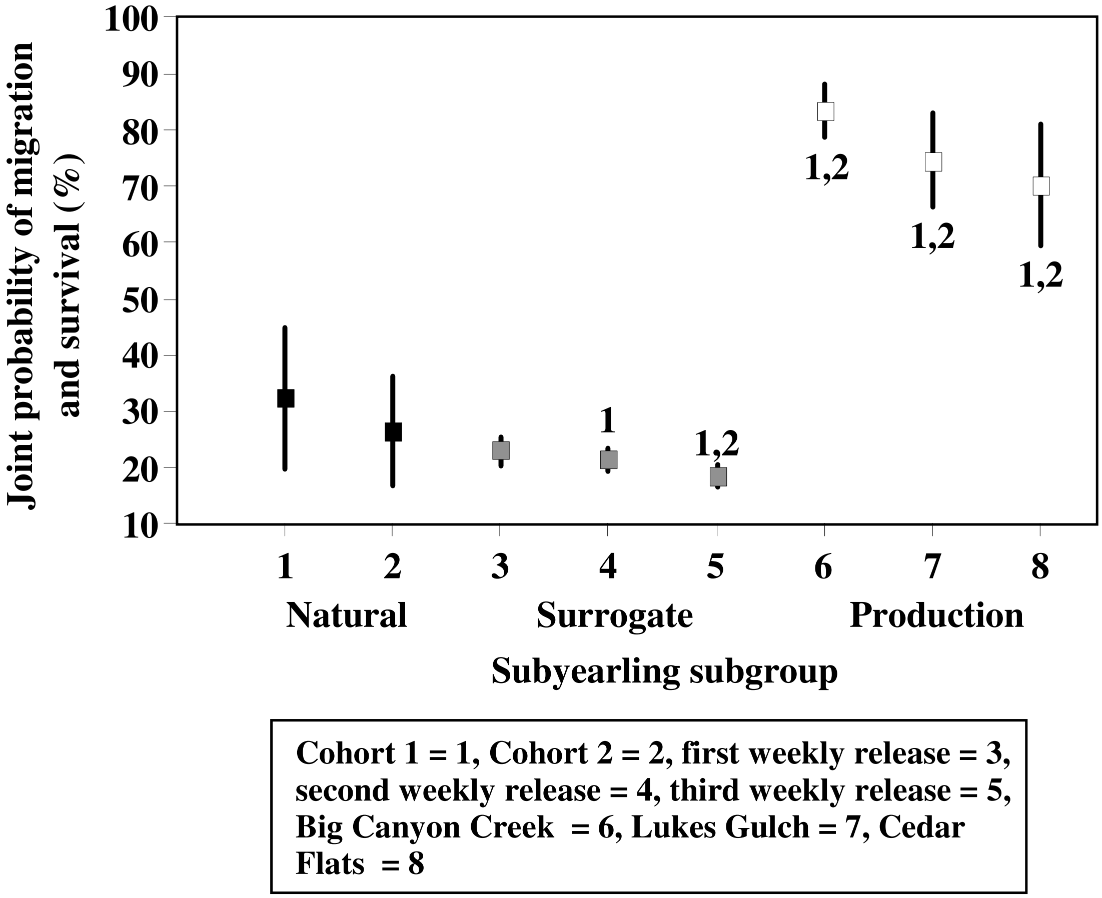

Figure 11.—The joint probability of migration and survival from release to the tailrace of Lower Granite Dam for subgroups of PIT-tagged Clearwater River natural, surrogate, and production fall Chinook salmon subyearlings in migration year 2008. A "1" above or below an estimate for a hatchery subgroup indicates a significant difference between the subgroup and the natural subyearling subgroup cohort 1.

Overall Comparison of Attributes

The indices for Clearwater River fish showed greater similarity between natural and surrogate subyearlings than between natural and production subyearlings (Table 8). Two of the similarity indices calculated for natural and surrogate subyearlings were 3.9 (a 290% difference). One was for percent detection during summer spill at Lower Granite Dam and the other was for cumulative detection at Lower Monumental Dam. The largest similarity index for natural and production subyearlings was for peak monthly detection at Lower Monumental Dam (a 544% difference). Based on mean and median similarity indices calculated by dam, the level of similarity in the attributes of natural and surrogate subyearlings did not change in a consistent pattern as fish moved downstream (Lower Granite Dam, mean 1.9, median 1.4; Little Goose (Dam, mean 1.1, median 1.1; Lower Monumental Dam, mean 1.1, median 1.2); whereas, on average the attributes of natural and production subyearlings became increasingly dissimilar as the fish moved downstream (Lower Granite Dam, mean 37.7; Little Goose Dam mean 100.0; Lower Monumental Dam, mean 169.4). However, consistent pattern was not evident in the median similarity indices calculated by dam for natural and production subyearlings (Lower Granite Dam, median 5.0; Little Goose Dam, median 100.0; Lower Monumental Dam, median 27.6). Overall, there was a 60% difference in the postrelease attributes of natural and surrogate subyearlings compared to a 9,732% difference between natural and production subyearlings.

Table 8.—Similarity indices (higher value divided by lower value of the attribute) for each comparison between 2008 releases of PIT-tagged Clearwater River natural and the two groups of hatchery fall Chinook salmon subyearlings. An index value of 1.0 would indicate no difference, while a value of 2.0 would indicate a two-fold difference. The attribute values are proportions except for migrant size (mm) and travel time (days). See page 19 for attribute descriptions.

Attribute	Attribute values		Similarity indices	Attribute values		Similarity indices
	Natural	Surrogates		Natural	Production	
			Lower Granite Dam			
Cumulative detection	0.284	0.648	2.3	0.037	0.994	27.1
Peak monthly detection	0.156	0.209	1.3	0.156	0.001	185.4
2008 detection	0.948	0.987	1.0	0.947	1.000	1.1
Summer spill detection	0.101	0.394	3.9	0.101	0.502	5.0
Travel time	106	77	1.4	106	21	5.0
Migration/survival	See Table A2		1.4	See Table A2		2.6
			Little Goose Dam			
Cumulative detection	0.800	0.676	1.2	0.040	0.947	23.7
Peak monthly detection	0.520	0.496	1.0	0.520	0.001	470.5
2008 detection	0.684	0.818	1.2	0.684	1.000	1.5
Summer spill detection	0.440	0.450	1.0	0.440	0.606	1.4
Travel time	71	85	1.2	71	24	3.0
			Lower Monumental Dam			
Cumulative detection	0.107	0.415	3.9	0.036	0.987	27.6
Peak monthly detection	0.821	0.556	1.5	0.821	0.001	644.4
2008 detection	0.440	0.356	1.2	0.440	0.003	153.9
Summer spill detection	0.036	0.044	1.2	0.036	0.508	14.2
Travel time	149	151	1.0	149	22	6.8
Overall mean			1.6			98.3
Overall median			1.2			10.5

DISCUSSION

Assumptions and Limitations

Our analysis on passage indices for the populations of natural juveniles at Lower Granite Dam were affected by differences in sampling efficiency across the season, an inability to sample every rearing area in the roughly 133 km of riverine habitat upstream of Lower Granite Reservoir, as well as the lack of representation of fish that disperse into the lower Snake River reservoirs at fork lengths less than 60 mm. However, the natural portion of study fish was generally a representative index of the overall natural population of fall Chinook salmon that reared upstream of Lower Granite Reservoir. We did not report the results of our analyses on passage indices at Little Goose and Lower Monumental dams because the supplying the PIT-tag detection systems with water for only part of each year biased the detection probability estimates. For example, when we estimated season-wide detection probability for groups of subyearlings at Little Goose Dam, they were typically low because many fish passed Little Goose Dam after its PIT-tag detection system was dewatered, but were subsequently detected at Lower Monumental Dam whose detection system was still operating. Therefore, the number of fish estimated to have passed Little Goose Dam was higher than the number estimated to have passed Lower Granite Dam. The same situation existed for Lower Granite and Lower Monumental dams because of the extended operation of the PIT-tag detection system at Ice Harbor Dam. Supplying water to the PIT-tag detection systems in the lower Snake River, or at least synchronizing when the water is supplied, would improve the ability to estimate detection probability. Moreover, identifying and selecting the most accurate and precise method for estimating detection probabilities will be critical to future evaluations of dam passage experiences.

When comparing postrelease attributes, we used the unexpanded detection data. We assumed that daily change in percent spill at the dams was not the sole factor for differences observed between natural subyearlings and the two hatchery subyearling groups. We believe the detection data met this assumption. Given two groups of subyearlings with similar or identical passage timing, a violation of this assumption would require some variation of this unlikely example: (1) during time t natural subyearlings passed the dams via the juvenile bypass and PIT-tag detection systems and production subyearlings passed under the submersible traveling screens or over the spillways and (2) during time $t + 1$ production subyearlings passed the dams via the juvenile bypass and PIT-tag detection systems and natural subyearlings passed under the submersible traveling screens or over the spillways. The large decrease in percent spill observed after 08/31/2008 undoubtedly exaggerated the difference between the postrelease attributes of Clearwater River natural and production subyearlings. However, large differences in the postrelease attributes of Clearwater River natural and production subyearlings were inevitable because Clearwater River production subyearlings were released at fork lengths averaging over 90 mm coincident to the emergence of 36-mm natural fry.

Objectives 1 and 2

The first objective of this report was to construct passage indices at Lower Granite Dam for Snake River basin natural and production juveniles. We found that passage of natural juveniles at Lower Granite Dam extended from spring 2008 to spring 2009; whereas, passage of production subyearlings was nearly complete by the end of summer 2008. This difference in passage timing reflects differences in the juvenile life history diversity and was the cumulative product of differences in rearing environment, growth, migration rate, migrational behavior, survival, and seasonal changes in the environment. The second objective of this report was to compare the postrelease performance of 2008 releases of natural subyearlings to the postrelease performance of 2008 releases of surrogate and production subyearlings separately for fish from the Snake and Clearwater rivers. This objective further explained the differences observed at Lower Granite Dam between natural and production juveniles and showed that these differences persisted and sometimes increased as the fish passed downstream. We found that there was an overall difference of 10% in the postrelease attributes of Snake River natural and surrogate subyearlings compared to a 250% difference between Snake River natural and production subyearlings. We also found that there was an overall difference of 60% in the postrelease attributes of Clearwater River natural and surrogate subyearlings compared to a 9,732% difference between Clearwater River natural and production subyearlings.

Consistent with our 2005 and 2006 findings (Connor et al. 2008a, b), we conclude the postrelease attributes measured on 2008 releases were more similar between Snake River and Clearwater River natural and surrogate subyearlings than between natural and production subyearlings from these two rivers. Consistent with the consensus proposal of Marsh et al. (2007b), we recommend providing (1) surrogate subyearlings for five release years to evaluate the response of natural subyearlings to dam passage strategies and (2) production subyearlings for five release years to evaluate the response of production subyearlings to dam passage experiences and to evaluate supplementation. As of the writing of this report in 2009, we have made one pilot release of surrogate subyearlings in 2005, three full-scale releases of surrogate subyearlings (2006, 2008, 2009), one pilot release of production subyearlings in 2006, and two full-scale releases of production subyearlings (2008 and 2009). The consensus study design (Marsh et al 2007), considers 2006 as the first official release year. As such, two more marked release years (2010 and 2011) remain to be implemented. Future consideration for additional releases in 2012 through 2016 will be based on preliminary results of 2005 to 2009 releases.

ACKNOWLEDGEMENTS

We thank the field crews of the Nez Perce Tribe and U. S. Fish and Wildlife Service for their many hours in the field. Extra recognition goes to staff of the Washington Department of Fish Wildlife staff at the Dayton Lab and Lyons Ferry Hatchery as well as the staff of Umatilla Hatchery, who spent many hours planning and coordinating to make the surrogate releases possible in 2008. We appreciate the efforts of BioMark, inter-agency, and tribal staff for PIT tagging the fish. R. Bohn reared the surrogates at Dworshak National Fish Hatchery with valuable assistance from M. Bright. This study (and many other studies we have conducted) would not have been possible without personnel of the Pacific States Marine Fisheries Commission, including D. Marvin, who operates and maintains the Columbia Basin PIT-tag Information System. Funding was provided by the U.S. Army Corps of Engineers Walla Walla District and Bonneville Power Administration projects 1983350003, 199102900, and 199801004. We greatly appreciate the contracting efforts of S. Dunmire, D. Docherty, and J. Sperber. Use of trade names does not imply endorsement by the U.S. National Marine Fisheries Service, U.S. Fish and Wildlife Service, or Nez Perce Tribe.

Table A1.—Approximate number of production fall Chinook salmon subyearlings released at each site (*N*) in 2008.

River	Site	*N*
Snake	Hells Canyon Dam from Oxbow Hatchery	193,000
	Hells Canyon Dam from Umatilla Hatchery	770,000
	Pittsburg Landing acclimation facility	402,000
	Captain John Rapids acclimation facility	513,000
	Couse Creek boat launch	230,000
	Cougar Creek	303,000
Clearwater	Big Canyon Creek acclimation facility	520,000
	Lukes Gulch acclimation facility	100,000
	Cedar Flats acclimation facility	100,000

Table A2.—Calculating similarity indices for comparing the joint probability of migration and survival (%) from release to the tailrace of Lower Granite Dam between PIT-tagged Snake and Clearwater River natural, surrogate, and production fall Chinook salmon subyearlings in migration year 2008. The mean index was used in Tables 5 and 8.

Group	Subgroup	Joint probability of migration and survival	Similarity indices vs. cohort 1	Similarity indices vs. cohort 2	Mean index
		Snake River			
Natural	Cohort 1	69.8			
	Cohort 2	51.2			
Surrogate	Release 1	68.1	1.0	1.3	1.2
	Release 2	61.2	1.1	1.2	
	Release 3	56.8	1.2	1.1	
Production	Hells Canyon	78.8	1.1	1.5	1.3
	Hells Canyon	81.0	1.2	1.6	
	Pittsburg Landing	78.9	1.1	1.5	
	CJ Rapids	86.1	1.2	1.7	
	Couse Creek	78.0	1.1	1.5	
	Cougar Creek	68.0	1.0	1.3	
		Clearwater River			
Natural	Cohort 1	32.7			
	Cohort 2	26.7			
Surrogate	Release 1	23.3	1.4	1.1	1.4
	Release 2	21.8	1.5	1.2	
	Release 3	18.7	1.8	1.4	
Production	Big Canyon	83.7	2.6	3.1	2.6
	Lukes Gulch	74.7	2.3	2.8	
	Cedar Flats	70.4	2.2	2.6	

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